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(54) **PLATELET-DERIVED GROWTH FACTOR COMPOSITIONS AND METHODS FOR THE TREATMENT OF TENDINOPATHIES**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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Related U.S. Application Data

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(60) Provisional application No. 61/429,428, filed on Jan. 3, 2011, provisional application No. 61/428,809, filed on Dec. 30, 2010, provisional application No. 61/311,284, filed on Mar. 5, 2010, provisional application No. 61/306,938, filed on Feb. 22, 2010.

(51) **Int. Cl.**
A61K 38/18 (2006.01)

(52) **U.S. Cl.**
CPC ***A61K 38/1858*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

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2008/0027470 A1 * 1/2008 Hart et al. 606/151

OTHER PUBLICATIONS

Chan et al., Clinical Orthopaedics and Related Research, 448:240-247, 2006.*
Mehta et al., Journal of Hand Therapy, 18:87-92, Apr.-Jun. 2005.*

* cited by examiner

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(74) *Attorney, Agent, or Firm* — Hilary Dorr Lang; Patterson Intellectual Property Law, PC

(57) **ABSTRACT**

Provided herein are compositions and methods for the treatment of tendinopathies, such as tenosynovitis, tendinosis or tendinitis, including Achilles tendinopathy, patellar tendinopathy, lateral epicondylitis or "tennis elbow," medial epicondylitis or "golfer's elbow," plantar fasciitis, and rotator cuff tendinopathy, and in particular to methods for the treatment of tendinopathies by administering compositions comprising platelet-derived growth factor (PDGF).

21 Claims, 12 Drawing Sheets

Figure 1.

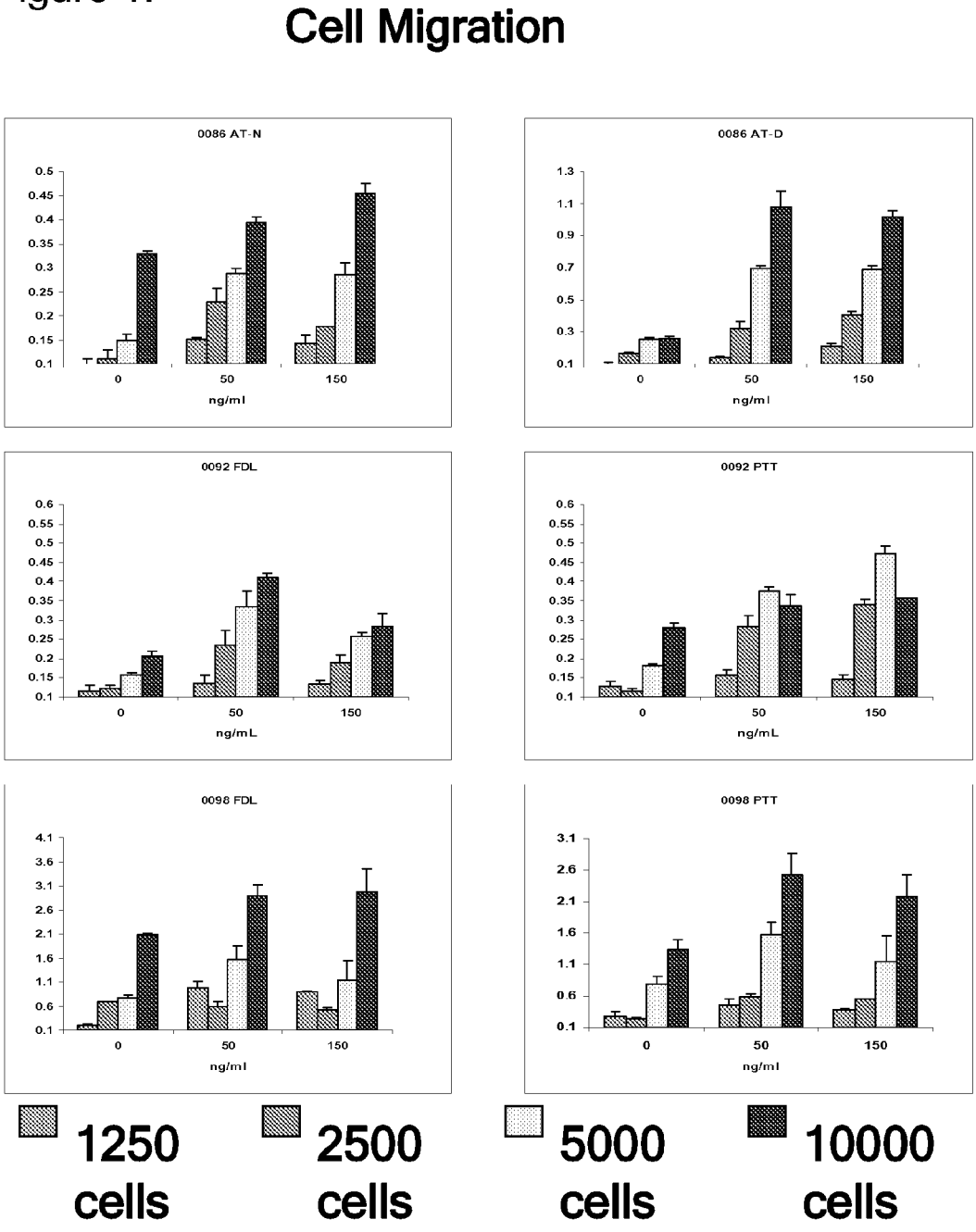

Cell Migration
0086 AT-N
0086 AT-D
0092 FDL
0092 PTT
0098 FDL
0098 PTT
ng/ml
ng/mL
1250 cells
2500 cells
5000 cells
10000 cells

Figure 2.

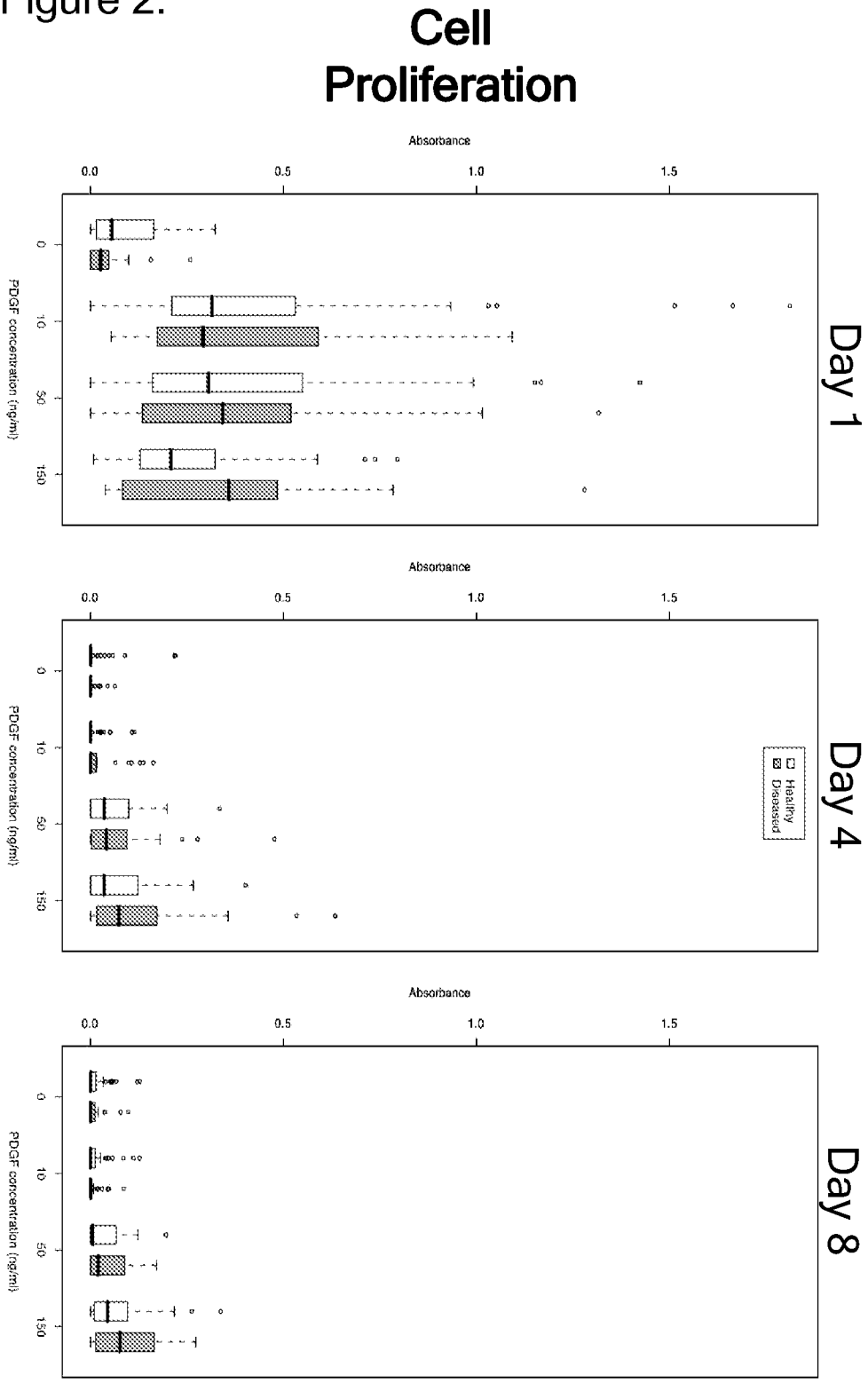

Cell Proliferation
Absorbance
0.0
0.5
1.0
1.5
PDGF concentration (ng/ml)
0
10
50
150
Day 1
Day 4
Day 8
Healthy
Diseased

Figure 3.

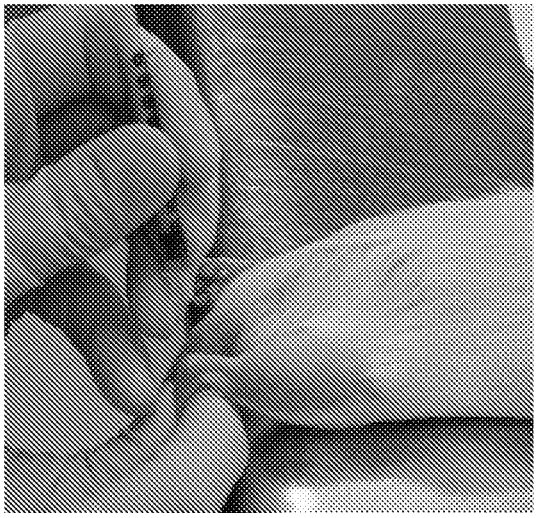


Figure 4.

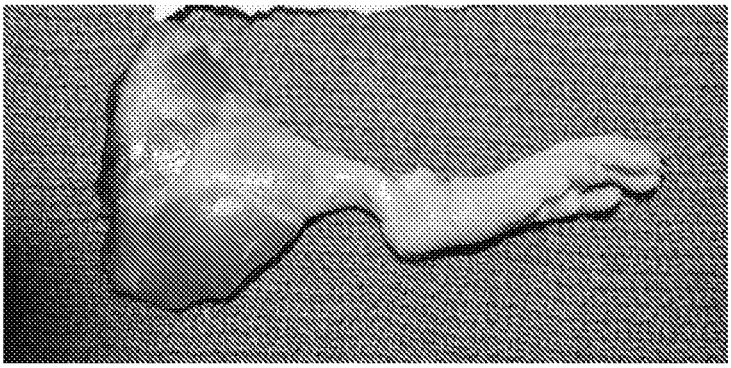


Figure 5.

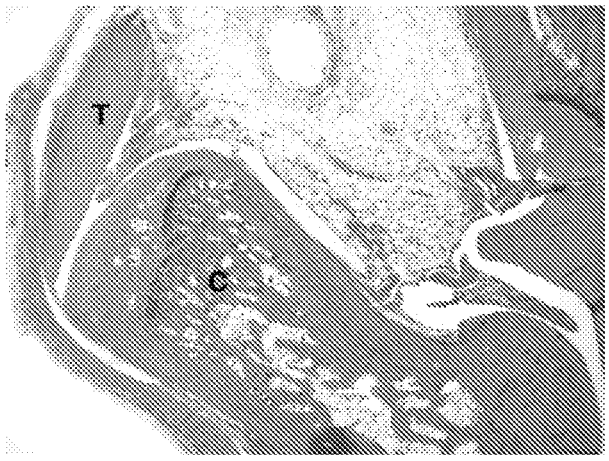


Figure 6A.

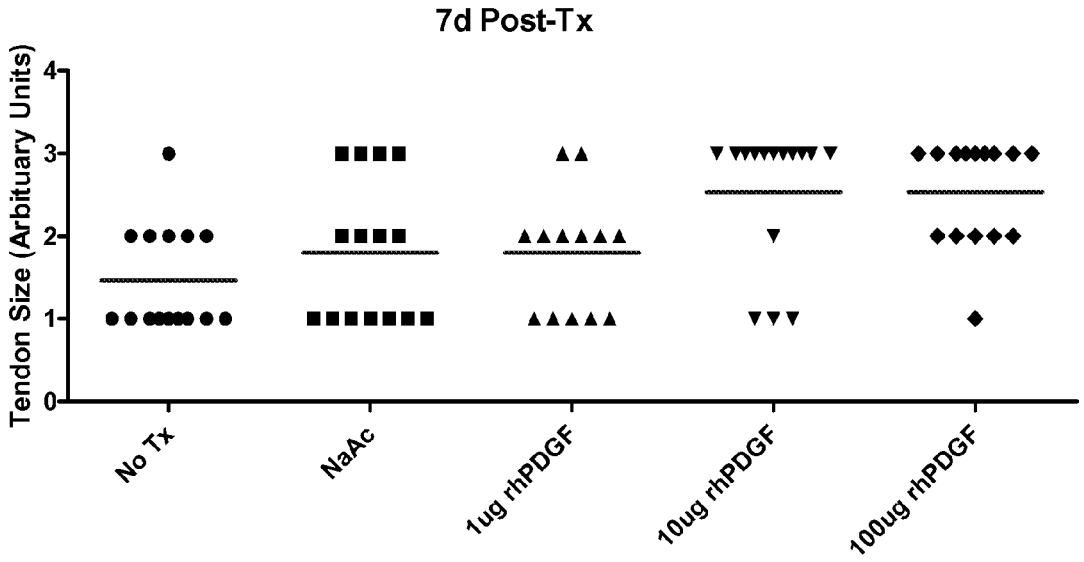
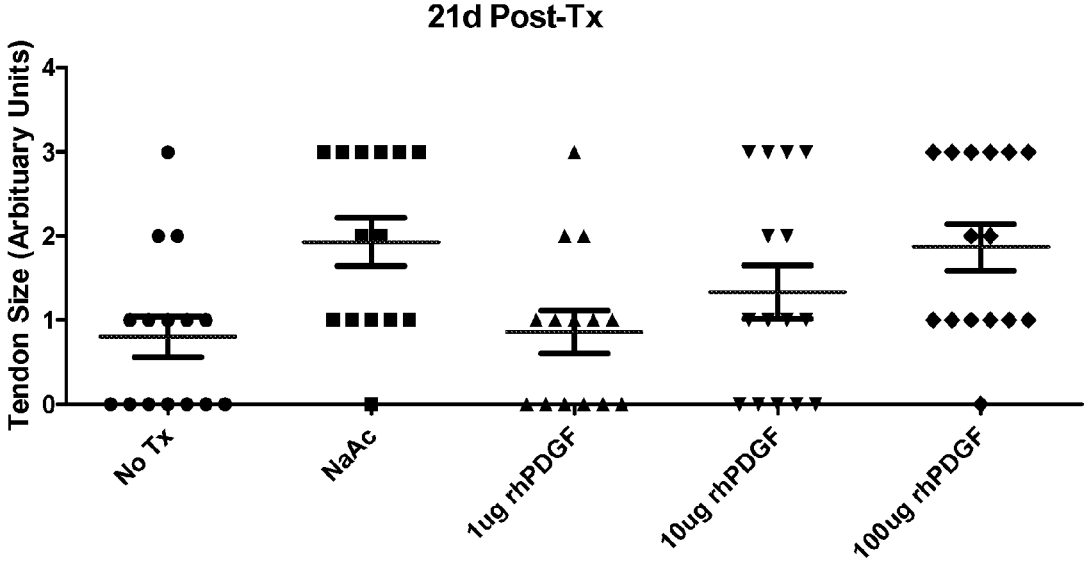


Figure 6B.



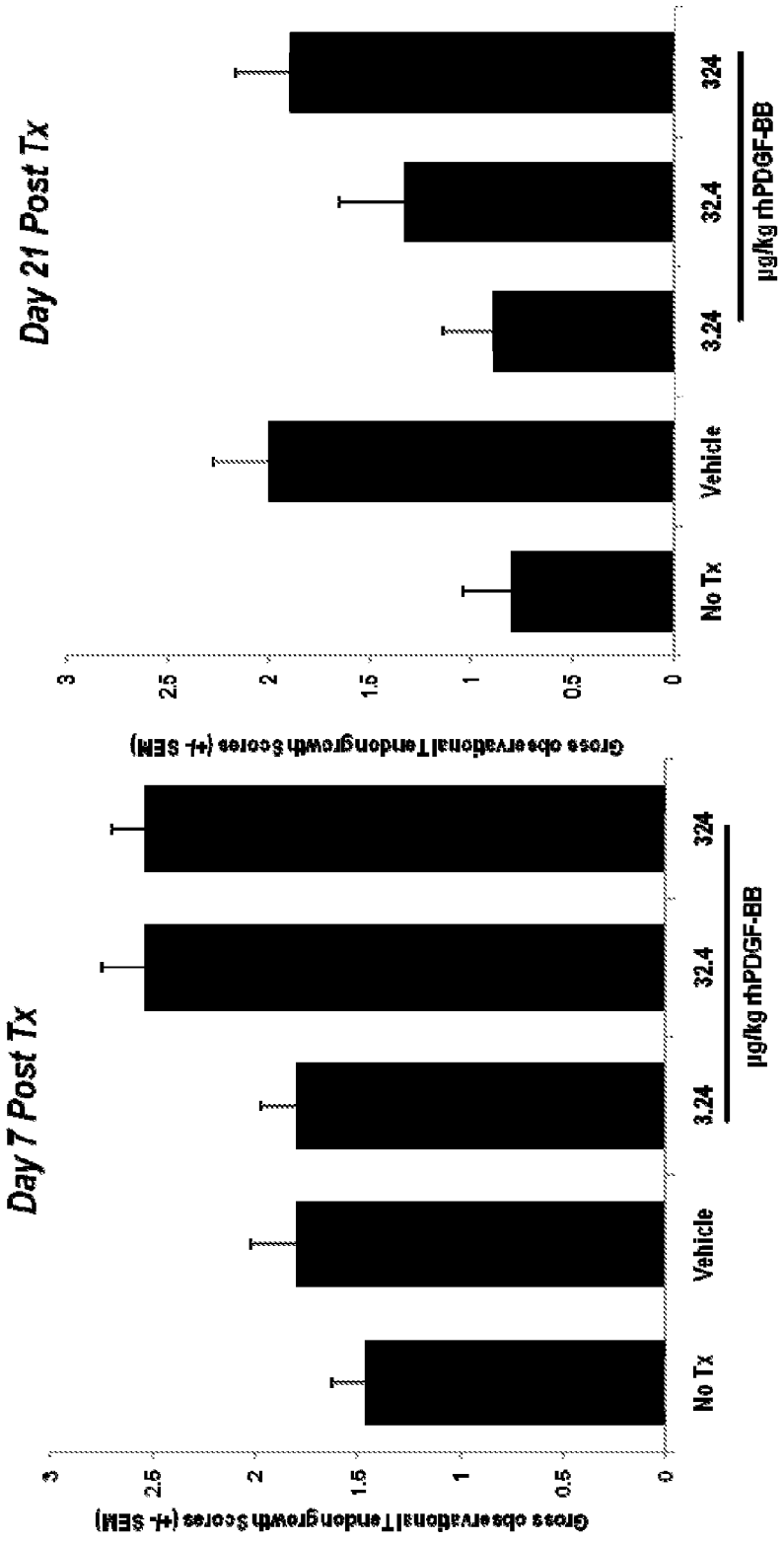

Day 7 Post Tx
Day 21 Post Tx
Gross observational Tendon growth Scores (+/- SEM)
0
0.5
1
1.5
2
2.5
3
No Tx
Vehicle
3.24
32.4
324
µg/kg rhPDGF-BB

Figure 7.

Figure 8.

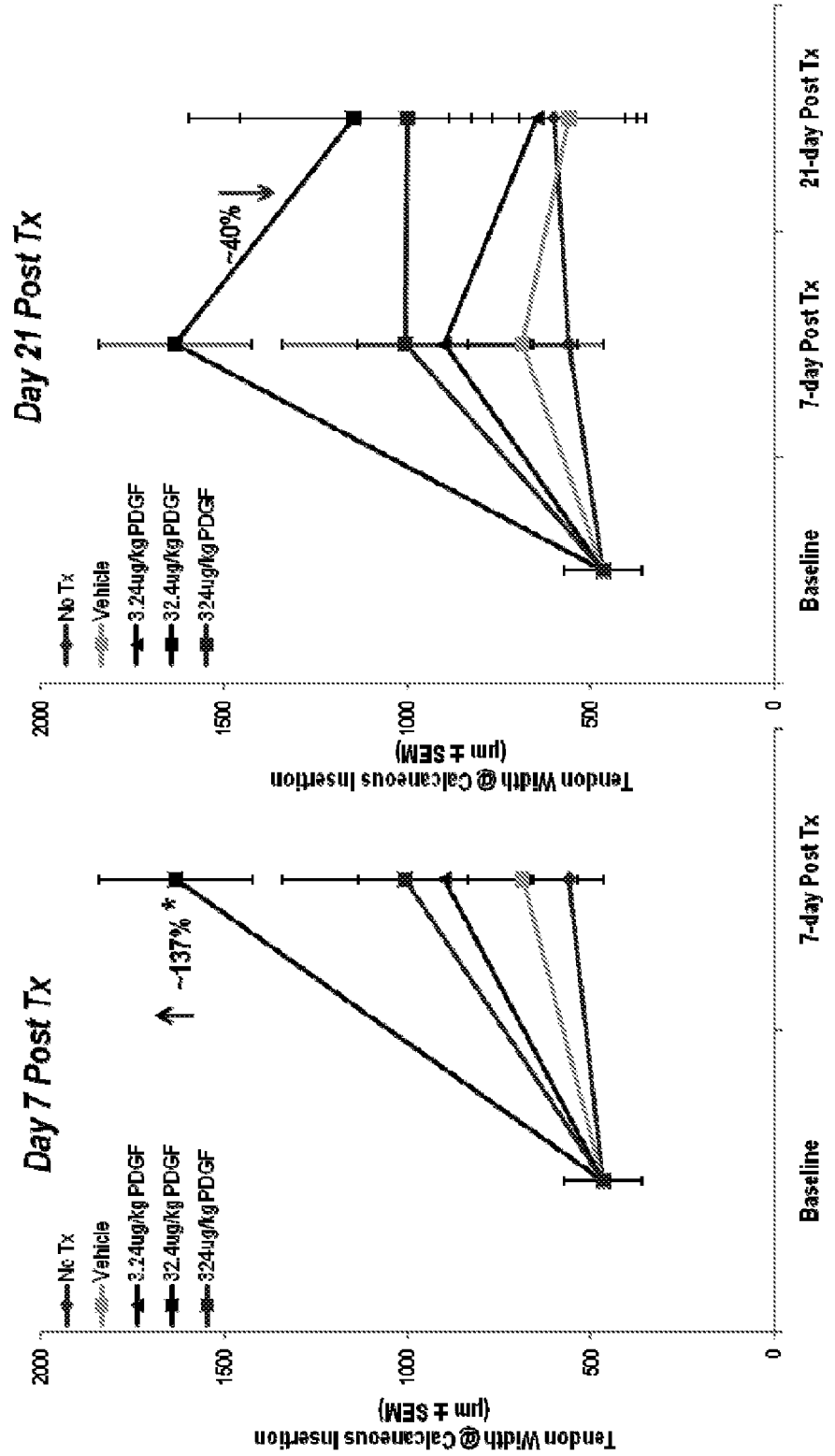

Day 7 Post Tx
Day 21 Post Tx
No Tx
Vehicle
3.24ug/kg PDGF
32.4ug/kg PDGF
324ug/kg PDGF
~137% *
~40%
Tendon Width @ Calcaneous Insertion
(µm ± SEM)
2000
1500
1000
500
0
Baseline
7-day Post Tx
21-day Post Tx

Figure 9.

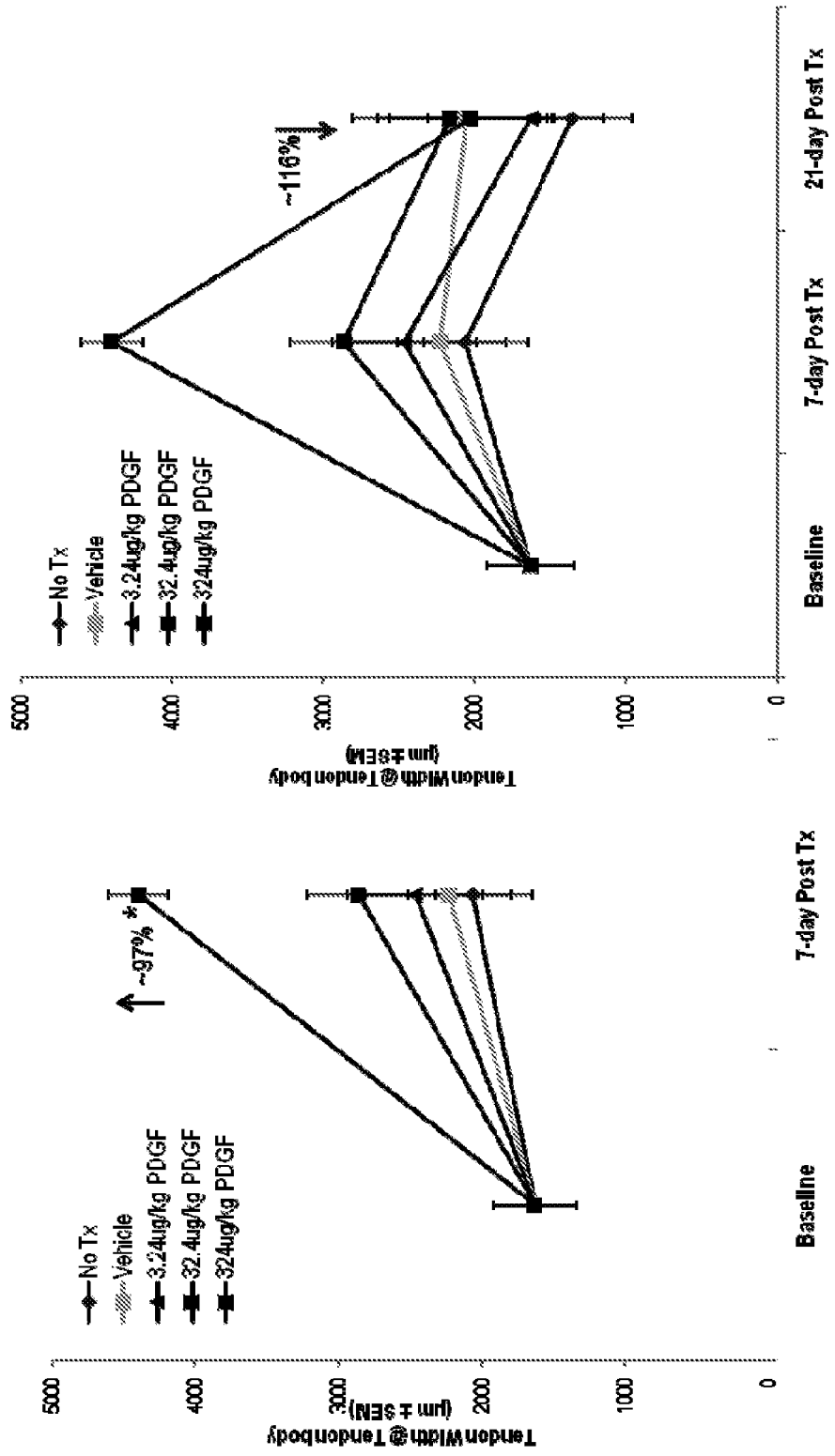

Day 7 Post Tx
Day 21 Post Tx
No Tx
Vehicle
3.24ug/kg PDGF
32.4ug/kg PDGF
324ug/kg PDGF
~97% *
~116%
Tendon Width @ Tendon body (µm ± SEM)
5000
4000
3000
2000
1000
0
Baseline
7-day Post Tx
21-day Post Tx

Figure 10.

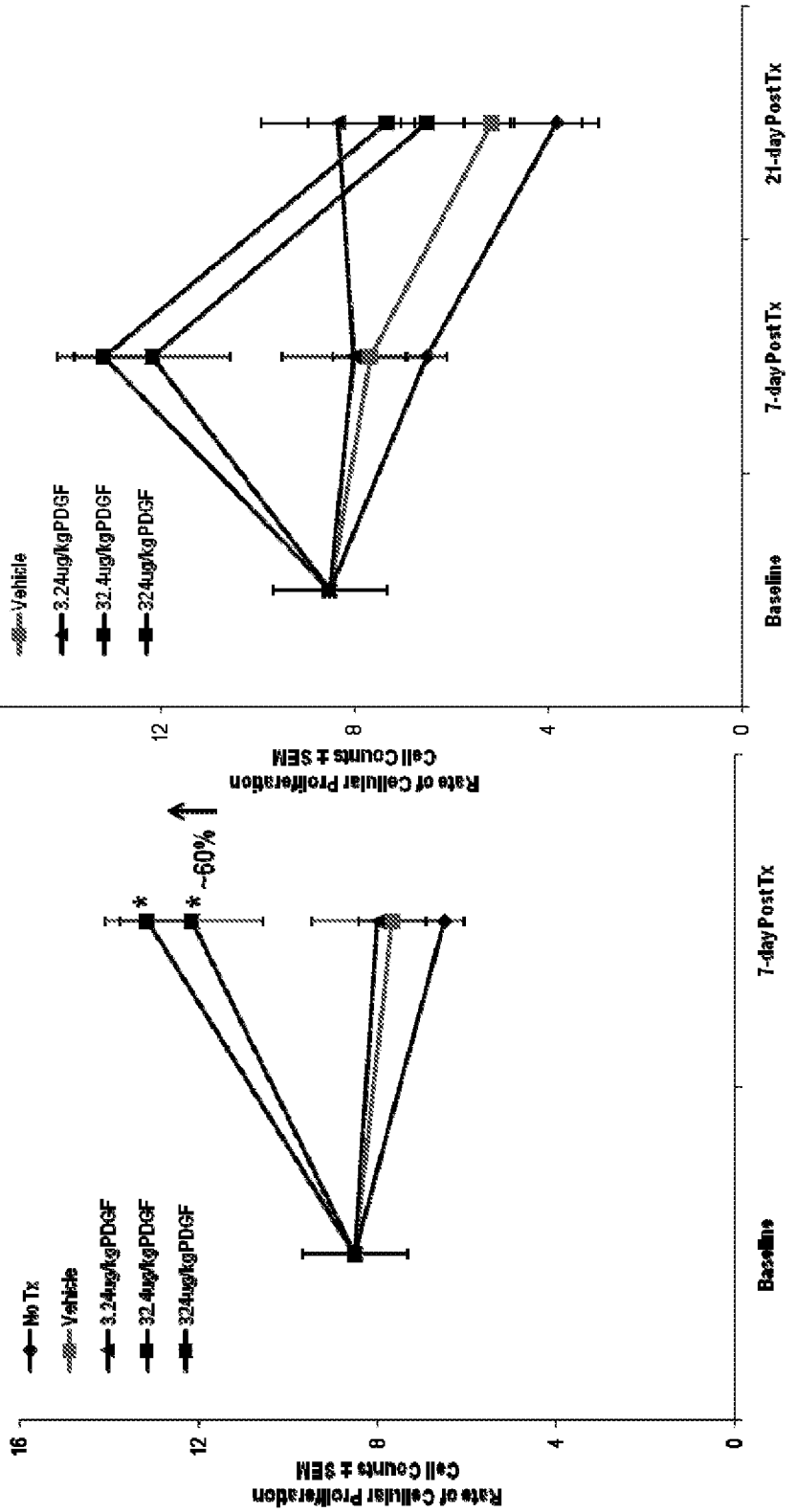
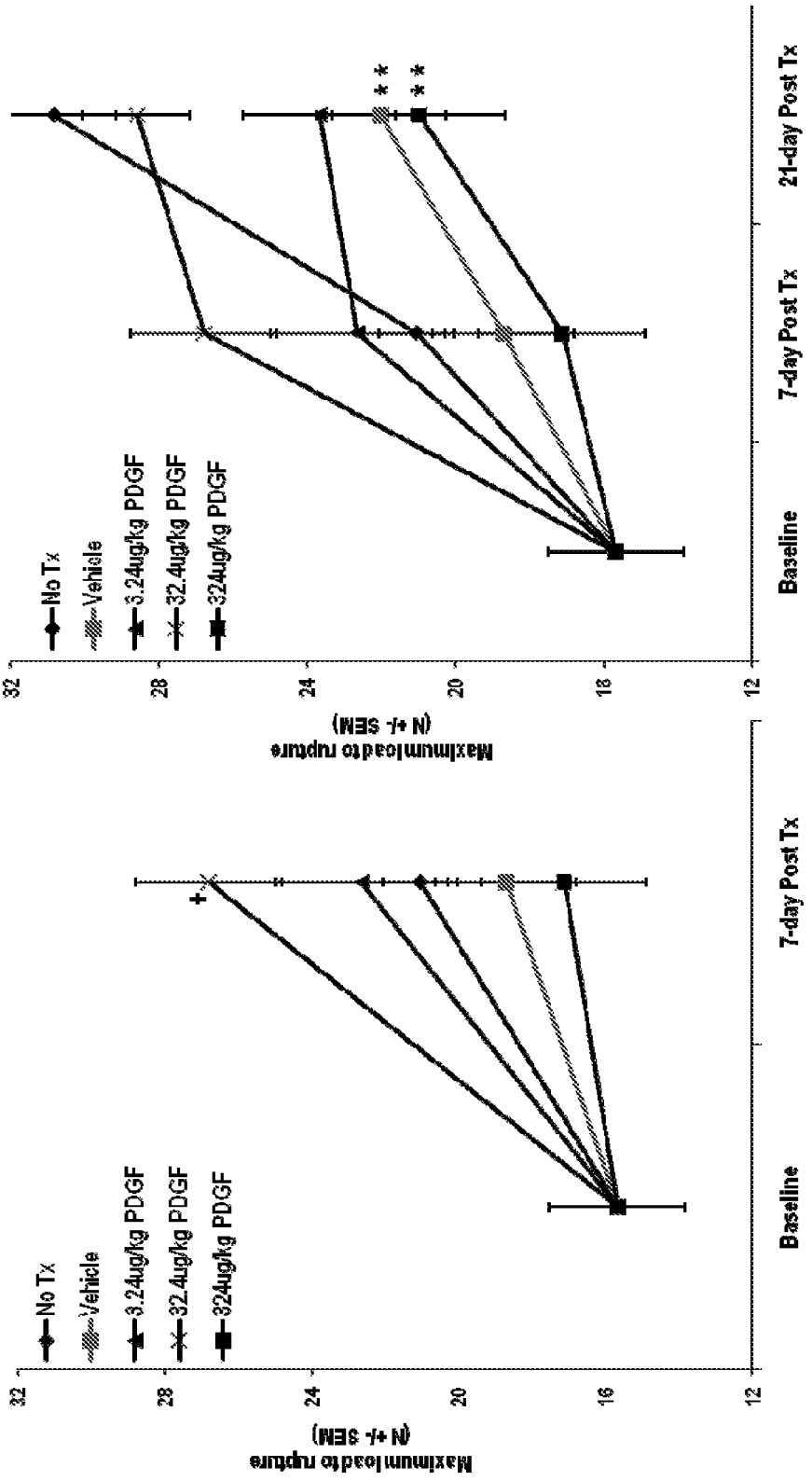

Day 7 Post Tx
Day 21 Post Tx
No Tx
Vehicle
3.24ug/kgPDGF
32.4ug/kgPDGF
324ug/kgPDGF
Rate of Cellular Proliferation
Cell Counts ± SEM
16
12
8
4
0
Baseline
7-day PostTx
21-day PostTx
*
*
~60%

Figure 11.


Day 7 Post Tx
Day 21 Post Tx
Maximum load to rupture
(N +/- SEM)
No Tx
Vehicle
3.24ug/kg PDGF
32.4ug/kg PDGF
324ug/kg PDGF
Baseline
7-day Post Tx
21-day Post Tx
32
28
24
20
16
12
18
* *
* *

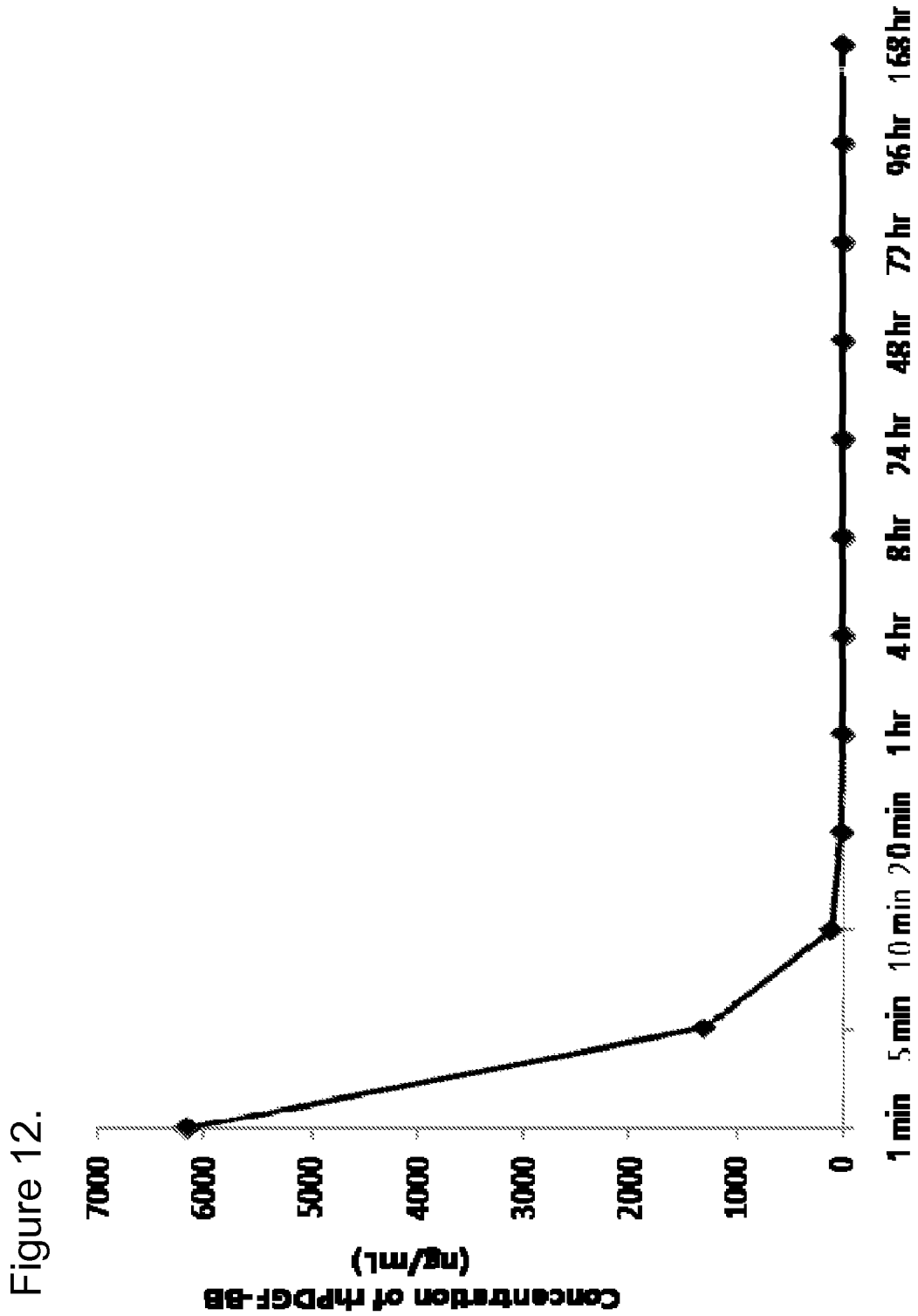

Concentration of rhPDGF-BB
(ng/mL)
7000
6000
5000
4000
3000
2000
1000
0
1 min
5 min
10 min
20 min
1 hr
4 hr
8 hr
24 hr
48 hr
72 hr
96 hr
168 hr

Figure 12.

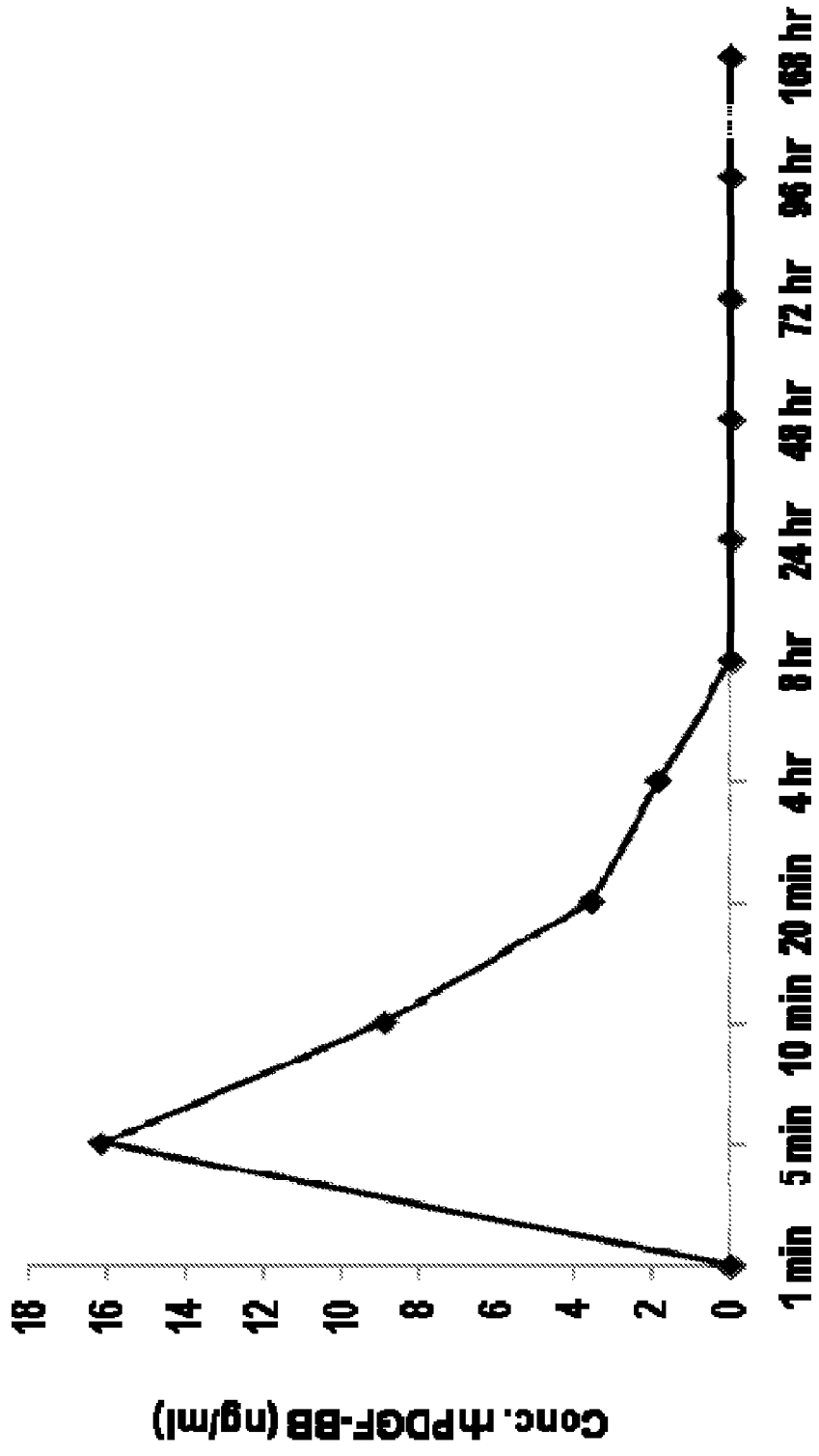
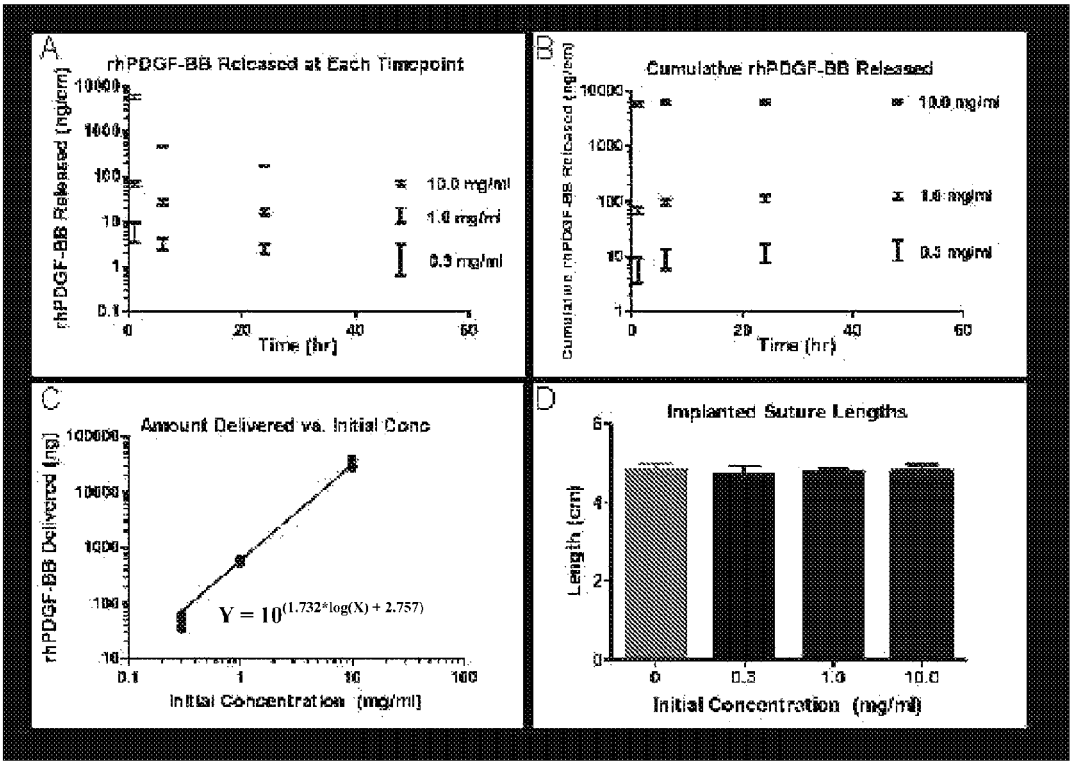

Conc. hPDGF-BB (ng/ml)
18
16
14
12
10
8
6
4
2
0
1 min
5 min
10 min
20 min
4 hr
8 hr
24 hr
48 hr
72 hr
96 hr
168 hr

Figure 13.

Figure 14.


A
rhPDGF-BB Released at Each Timepoint
rhPDGF-BB Released (ng/cm)
10000
1000
100
10
1
0.1
0
20
40
60
Time (hr)
10.0 mg/ml
1.0 mg/ml
0.3 mg/ml
B
Cumulative rhPDGF-BB Released
Cumulative rhPDGF-BB Released (ng/cm)
10000
1000
100
10
1
0
20
40
60
Time (hr)
10.0 mg/ml
1.0 mg/ml
0.3 mg/ml
C
Amount Delivered vs. Initial Conc
rhPDGF-BB Delivered (ng)
100000
10000
1000
100
10
0.1
1
10
100
Y = 10^(1.732*log(X) + 2.757)
Initial Concentration (mg/ml)
D
Implanted Suture Lengths
Length (cm)
6
4
2
0
0
0.3
1.0
10.0
Initial Concentration (mg/ml)

PLATELET-DERIVED GROWTH FACTOR COMPOSITIONS AND METHODS FOR THE TREATMENT OF TENDINOPATHIES

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 13/032,489, filed Feb. 22, 2011, now U.S. Pat. No. 8,492,335, which claims the benefit of U.S. Provisional Patent Application No. 61/306,938, filed Feb. 22, 2010, U.S. Provisional Patent Application Ser. No. 61/311,284, filed Mar. 5, 2010, U.S. Provisional Patent Application Ser. No. 61/428,809, filed Dec. 30, 2010, and U.S. Provisional Patent Application No. 61/429,428, filed Jan. 3, 2011, all of which are incorporated by reference herein in their entireties.

TECHNICAL FIELD

This invention relates to compositions and methods for the treatment of tendinopathies, such as tenosynovitis, tendinosis or tendinitis, including Achilles tendinopathy, patellar tendinopathy, lateral epicondylitis or "tennis elbow," medial epicondylitis or "golfer's elbow," plantar fasciitis, and rotator cuff tendinopathy, and in particular to methods for the treatment of tendinopathies by administering compositions comprising platelet-derived growth factor (PDGF).

BACKGROUND OF THE INVENTION

A tendon is a tough band of fibrous connective tissue that usually connects muscle to bone. The elastic properties of tendons modulate forces during locomotion, providing additional stability with no active work. They also store and recover energy at high efficiency. Normal healthy tendons are composed primarily of parallel arrays of type I collagen fibers closely packed together, but also include a small amount of elastin and of proteoglycans. Due to their highly specialized ultrastructure, low level of vascularization and slow collagen turnover, tendons are very slow to heal if injured, and rarely regain their original strength. Partial tears heal by the rapid production of disorganized type-III collagen, which is weaker than normal tendon. Recurrence of injury in the damaged region of tendon is common.

Tendinopathies are chronic disorders or injuries of the tendons, that appear to result from an imbalance between catabolic and anabolic responses that result from gradual wear and tear to the tendon from overuse or aging. The result of this imbalance is tendon degeneration, weakness, tearing, and pain. In contrast, acute tendon injuries such as, for example, tendon rupture or detachment from the bone are quite sudden and usually require surgery to repair the rupture or reattach the tendon to bone. Anyone can develop a tendinopathy, but people who tend to make the same motions over and over again in their jobs, sports, or regular daily activities are more likely to develop them. Tendinopathy usually causes pain, stiffness, and loss of strength in the affected area.

The term tendinopathy refers to two types of tendon injury: tendinosis and tendinitis. The term also encompasses tenosynovitis, a tendinopathy of the outer lining of the tendon which occurs in certain tendons such as flexor tendons and the Achilles tendon.

Tendinosis is a non-inflammatory injury to the tendon characterized by intratendinous degeneration of the tendon usually in the form of microtears in the tissue in and around

the tendon caused by overuse, leading to an increase in the number of tendon repair cells around the area of damage. Degeneration of the tendon is caused by damage to or disorganization of the collagen fibers, cells, and vascular components of the tendon, which can reduce the tendon's tensile strength and can lead to tendon rupture if not treated. The changes in collagen organization are characterized by separation/loosening/crimping of fibers, loss of parallel orientation, decrease in fiber diameter and decrease in overall density of collagen. In addition, collagen microtears can also occur that are surrounded by erythrocytes, fibrin, and fibronectin deposits. On the other hand, there is an increase in type III (reparative) collagen. These matrix organization changes can lead to decreased birefringence under polarized light microscopy. In addition to collagen content and organization, tendinosis is also characterized by an increase in mucoid ground substance (proteoglycans) and variation in cellular density in affected areas. Some areas contain abnormally plentiful tenocytes, with rounded nuclei and ultrastructural evidence of increased production of proteoglycan and protein. In contrast, other areas of the affected tendon may contain fewer tenocytes than normal, with small, pyknotic nuclei. Another characteristic feature of tendinosis is proliferation of capillaries and arterioles. Several subcategories of tendon degeneration in tendinosis have been identified by electron microscopy: (1) hypoxic degeneration, (2) hyaline degeneration, (3) mucoid or myxoid degeneration, (4) fibrinoid degeneration, (5) lipoid degeneration, (6) calcification, and (7) fibrocartilaginous and bony metaplasia. These pathologies can coexist with varying prevalence, depending on the anatomical site and the nature of the insult that caused them (eg, hypoxia versus mechanical loading; acute versus chronic injury). For example, mucoid degeneration area is characterized by light microscopy, large mucoid patches and vacuoles between fibers. However, lipoid degeneration is characterized by abnormal intratendinous accumulation of lipid that results in disruption of collagen fiber structure. In some cases, tendinosis is accompanied by focal necrosis or calcification of the tendon. It is a very common reason for chronic pain surrounding a joint. Tendinosis is also characterized by an absence of the initial inflammatory response. Inflammatory cells are thought to be early stage mediators of the repair process, without which tendinosis can become a chronic condition.

Characteristic increases in water content and disorganization of the collagen matrix associated with tendinosis can be diagnosed by ultrasonography or magnetic resonance imaging. Symptoms can vary from simple aching and stiffness in the local area of the tendon to a burning sensation surrounding the entire joint around the injured tendon. For many patients, the pain is frequently worse during and after activity, and the tendon and joint area can become stiffer the following day as swelling impinges on the movement of the tendon.

Tendinitis is an inflammatory injury to the tendon, characterized by degeneration like that observed in tendinosis, but also accompanied by inflammation of the tendon accompanied by vascular disruption and an inflammatory repair response. Tendinitis is often accompanied by fibroblastic and myofibroblastic proliferation, as well as hemorrhage and organizing granulation tissue. Generally tendinitis is referred to by the body part involved, such as Achilles tendinitis (affecting the Achilles tendon), or patellar tendinitis (also known as "jumper's knee," affecting the patellar tendon), though there are certain exceptions, such as lateral epicondylitis (also known as "tennis elbow," affecting the Extensor Carpi Radialis Brevis tendon). Symptoms can vary

from aches or pains and local stiffness to a burning sensation surrounding the entire joint around the inflamed tendon. In some cases, tendonitis is characterized by swelling, sometimes accompanied by heat and redness; there may also be visible knots surrounding the joint. For many patients, the pain is usually worse during and after activity, and the tendon and joint area can become stiffer the following day as muscles tighten from the movement of the tendon.

Current treatments are primarily palliative in nature, with treatment traditionally focusing on anti-inflammatory measures, including treatment with nonsteroidal anti-inflammatory drugs (NSAIDs), steroid injections, and physical therapy, despite the fact that tendinosis tends not to be associated with an inflammatory response. More recently, shock wave therapy, low-level laser therapy, sclerotherapy, and other experimental treatments have been tested. For the most part, it appears that some treatments (e.g., NSAIDs and cortisone injections) offer short-term relief, while the longer-term benefit of current treatments remains unclear. Therefore, there is a need for improved methods of treating tendinopathies that offer longer-term benefits compared to existing treatment modalities.

PDGF is stored in the alpha-granules of platelets and is secreted during tissue repair by locally-activated cells, including macrophages, fibroblasts, and endothelial cells. PDGF-BB is one of the major products of the hemorrhage and inflammation of acute tendon injury. Platelet-derived growth factor-BB (PDGF-BB) is a wound healing protein which is known to be chemotactic (cell migration) and mitogenic (cell proliferation) for cells of mesenchymal origin, including bone (osteoblast) and tendon (tenocyte) cells. Additionally, PDGF-BB has been shown to up-regulate vascular endothelial growth factor (VEGF), leading to increased angiogenesis (revascularization), which is essential for successful regenerative processes.

The Achilles tendon is the thickest and strongest tendon in the human body, which allows it to support high loads. The mechanical loading environment in which the Achilles tendon functions makes it prone to rupture. Achilles tendon ruptures can occur as a result of a variety of factors, however rupture is often associated with degenerative changes. (Mafulli N, Wong J, Almekinders L. Types and epidemiology of tendinopathy. *Clinics in Sports Medicine.* 2003; 22:675-692). Following the repair process, ruptured Achilles tendons demonstrate a reduction in type I collagen and a relative increase in the amount of type III collagen. This change in composition leads to less cross-linking and reduced tensile strength. Even after healing, a ruptured Achilles tendon remains weaker due to hypercellularity, disorganization, and decreased collagen cross-linking (Maffulli N, Moller H D, Evans C H. Tendon Healing: Can it be Optimized? British Journal of Sports Medicine, 2002; 36:315-316). Controversy exists regarding the optimal treatment for Achilles tendon ruptures, with pros and cons to both conservative (non-operative) and surgical therapies. Non-operative treatment results in a higher re-rupture rate and decreased strength but avoids the costs and risks associated with surgery. (Inglis A E, Scott W N, Sculco T P, et al. Ruptures of the tendo achillis: an objective assessment of surgical and nonsurgical treatment. J Bone Joint Surg Am. 1976; 58:990-993; Nistor L. Surgical and Nonsurgical treatment of Achilles tendon rupture: a prospective randomized trial. J Bone Joint Surg Am 1981 63(3):394-9; Chalmers J. Review Article: Treatment of Achilles tendon ruptures. Journal of Orthopaedic Surgery 200 8(1):97-99). Surgical repair carries with it the risks of surgery and anesthesia; however it provides increased strength, lower re-rupture rates and a earlier return to athletic activities. (Nistor L. Surgical and Nonsurgical treatment of Achilles tendon rupture: a prospective randomized trial. J Bone Joint Surg Am 1981 63(3):394-9; Rettig A, Liotta F J, Klootwyk T E, Porter D A, Mieling P. Potential Risk of Rerupture in Primary Achilles Tendon Repair in Athletes Younger than 30 years of Age. Am J of Sports Med 2005:33(1):119-123) Regardless of a clinician's preference for treatment of acute Achilles tendon ruptures, surgical repair will continue to have its place in the spectrum of treatment of these injuries in the active patient population. Augmentation of the biological repair process, thereby improving tendon healing, could potentially lead to a faster return to activity and improved clinical outcomes compared to current treatment modalities.

There have been several in vivo and in vitro studies regarding biologic augmentation of tendon healing. See e.g.: Seeherman H J, Archambault J M, Rodeo S A, et al. rhBMP-12 accelerates healing of rotator cuff repairs in a sheep model. *J Bone Joint Surg Am.* 2008; 90(10):2206-2219; Chan B P, Fu S C, Qin L, et al. Supplementation-time dependence of growth factors in promoting tendon healing. *Clin Orthop Relat Res.* 2006; 448:240-247; Uggen J C, Dines J, Uggen C W, et al. Tendon gene therapy modulates the local repair environment in the shoulder. *J Am Osteopath Assoc.* 2005; 105(1):20-21; Gelberman R, Thomopoulos S, Sakiyama-Elbert S, et al. The early effects of sustained platelet-derived growth factor administration on the functional and structural properties of repaired intrasynovial flexor tendons: an in vivo biomechanic study at 3 weeks in canines. *J Hand Surg Am.* 2007; 32(3):373-379; Thomopoulos S, Das R, Silva M J, et al. Enhanced flexor tendon healing through controlled delivery of PDGF-BB. *J Orthop Res.* 2009; 27(9):1209-1215; Thomopoulos S, Zaegel M, Das R, et al. PDGF-BB released in tendon repair using a novel delivery system promotes cell proliferation and collagen remodeling. *J Orthop Res.* 2007; 25(10):1358-1368; Dines J, Grande D, Dines D. Tissue Engineering and Rotator Cuff Tendon Healing. J Shoulder Elbow Surg, September/October 2007: 204S-206S.

Delivering rhPDGF-BB to the site of repair in sufficient doses and over the proper time-course is important in achieving the desired clinical effect. Several studies describe sutures coated with biologics. See e.g. Rickert M, Jung M, Adiyaman M, Richter W, Wimank H G. Growth and differentiation factor 5 coated suture stimulates tendon healing in an Achilles tendon model in rats. Growth Factors 2001; 19:115-126; Weiler A, Forster C, Hunt P, Falk R, Jung T, Unterhauser F N, Bergmann V, Schmidmaier G, Haas N P. The Influence of Locally Applied Platelet-Derived Growth Factor-BB on Free Tendon Graft Remodeling After Anterior Cruciate Ligament Reconstruction. American Journal of Sports Medicine 2004; 32(4):881-891; Dines J, Weber L, Razzano P, et al. The Effect of Growth Differentiation Factor-5-Coated Sutures on Tendon Repair in a Rat Model. J Shoulder Elbow Surg 2007; 16:2155-2215; Uggen C, Dines J, McGarry M, et al. The effect of Recombinant Human Platelet Derived growth Factor BB coated sutures on Rotator cuff Healing in a Sheep Model. Arthroscopy: 2010: 26(11): 1456-1462.

What is needed are improved sutures for delivery of PDGF to a tendon, for example, for repair of ruptured tendon such as ruptured Achilles tendons.

SUMMARY

In one aspect, provided herein is a method of treating a tendinopathy comprising administering to an affected site an

effective amount of a composition comprising a PDGF and a buffer. In some embodiments, the tendinopathy is a tendinosis. In some embodiments, the tendinopathy is a tendinitis. In some embodiments, the tendinopathy is a tenosynovitis. In some embodiments, the PDGF is selected from the group consisting of PDGF-AA, PDGF-BB, PDGF-AB, PDGF-CC, and PDGF-DD. In some embodiments, the PDGF is PDGF-BB. In some embodiments, the PDGF is recombinant human (rh) PDGF-BB. In some embodiments, the effective amount of the composition comprises between about 75 μg and about 7,500 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises between about 500 μg to about 1,000 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises between about 5,000 μg to about 7,500 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises between about 450 μg to about 3000 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises between about 400 μg to about 1000 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises between about 500 μg to about 900 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises between about 600 μg to about 800 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises between about 650 μg to about 750 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises about 700 μg of PDGF-BB per dose. In some embodiments, the composition has a volume of about 1.0 to about 2.0 ml per dose. In some embodiments, the composition has a volume of about 1.5 ml per dose. In some embodiments, the buffer is selected from the group consisting of phosphate-buffered saline ("PBS"), sodium acetate, ammonium acetate, acetic acid, citric acid, sodium citrate, tris(hydroxymethyl)aminoethane ("tris"), N-2-hydroxyethylpiperazine-N'-2-ethanesulfonic acid ("HEPES"), 3-(N-morpholino) propanesulfonic acid ("MOPS"), 2-(N-morpholino)ethanesulfonic acid ("MES"), N-(2-acetamido)iminodiacetic acid ("ADA"), piperazine-N, N'-bis(2-ethanesulfonic acid) ("PIPES"), and N-(2-acetamido)-2-aminoethanesulfonic acid ("ACES"). In some embodiments, the buffer is sodium acetate. In some embodiments, the sodium acetate is at a concentration between about 10 mM and about 100 mM. In some embodiments, the sodium acetate is at a concentration of about 20 mM. In some embodiments, the composition has a pH between about 4.0 and about 7.0. In some embodiments, the composition has pH of about 6. In some embodiments, the administering is by direct injection to the affected site. In some embodiments, the affected site is an osseous-tendon junction. In some embodiments, the affected site is a tendon. In some embodiments, the tendinopathy is selected from the group consisting of Achilles tendinopathy, patellar tendinopathy, lateral epicondylitis, medial epicondylitis, plantar fasciitis, and rotator cuff tendinopathy. In some embodiments, the tendinopathy is lateral epicondylitis. In some embodiments, the composition is administered as a single dose. In some embodiments, the composition is administered by a single injection. In some embodiments, the composition is administered in more than one dose. In some embodiments, the composition is administered by a single injection once a week for four weeks. In some embodiments, the method results in an increase in tendon strength of at least about 60% within about 7 days of administration, as compared to baseline. In some embodiments, the method results in an increase in tendon strength of at least about 65% within about 7 days of administration, as compared to baseline. In some embodiments, the method results in an increase in tendon strength of at least about 70% within about 7 days of administration, as compared to baseline. In some embodiments, the method results in the tendon achieving at least about 80% of its final strength within about 7 days of administration, wherein final strength is measured at about 21 days after administration. In some embodiments, the method results in the tendon achieving at least about 85% of its final strength within about 7 days of administration, wherein final strength is measured at about 21 days after administration. In some embodiments, the method results in the tendon achieving at least about 90% of its final strength within about 7 days of administration, wherein final strength is measured at about 21 days after administration.

In another aspect, provided herein is a method of treating a tendinopathy comprising administering to an affected site an effective amount of a composition consisting of a PDGF and a buffer. In some embodiments, the tendinopathy is a tendinosis. In some embodiments, the tendinopathy is a tendinitis. In some embodiments, the tendinopathy is a tenosynovitis. In some embodiments, the PDGF is selected from the group consisting of PDGF-AA, PDGF-BB, PDGF-AB, PDGF-CC, and PDGF-DD. In some embodiments, the PDGF is PDGF-BB. In some embodiments, the PDGF is recombinant human (rh) PDGF-BB. In some embodiments, the effective amount of the composition comprises between about 75 μg and about 7,500 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises between about 500 μg to about 1,000 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises between about 5,000 μg to about 7,500 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises between about 450 μg to about 3000 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises between about 400 μg to about 1000 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises between about 500 μg to about 900 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises between about 600 μg to about 800 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises between about 650 μg to about 750 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises about 700 μg of PDGF-BB per dose. In some embodiments, the composition has a volume of about 1.0 to about 2.0 ml per dose. In some embodiments, the composition has a volume of about 1.5 ml per dose. In some embodiments, the buffer is selected from the group consisting of phosphate-buffered saline ("PBS"), sodium acetate, ammonium acetate, acetic acid, citric acid, sodium citrate, tris(hydroxymethyl)aminoethane ("tris"), N-2-hydroxyethylpiperazine-N'-2-ethanesulfonic acid ("HEPES"), 3-(N-morpholino) propanesulfonic acid ("MOPS"), 2-(N-morpholino)ethanesulfonic acid ("MES"), N-(2-acetamido)iminodiacetic acid ("ADA"), piperazine-N, N'-bis(2-ethanesulfonic acid) ("PIPES"), and N-(2-acetamido)-2-aminoethanesulfonic acid ("ACES"). In some embodiments, the buffer is sodium acetate. In some embodiments, the sodium acetate is at a concentration between about 10 mM and about 100 mM. In some embodiments, the sodium acetate is at a concentration of about 20 mM. In some embodiments, the composition has a pH between about 4.0 and about 7.0. In some embodiments, the composition has pH of about 6. In some embodiments, the administering is by direct injection to the affected site. In

some embodiments, the affected site is an osseous-tendon junction. In some embodiments, the affected site is a tendon. In some embodiments, the tendinopathy is selected from the group consisting of Achilles tendinopathy, patellar tendinopathy, lateral epicondylitis, medial epicondylitis, plantar fasciitis, and rotator cuff tendinopathy. In some embodiments, the tendinopathy is lateral epicondylitis. In some embodiments, the composition is administered as a single dose. In some embodiments, the composition is administered by a single injection. In some embodiments, the composition is administered in more than one dose. In some embodiments, the composition is administered by a single injection once a week for four weeks. In some embodiments, the method results in an increase in tendon strength of at least about 60% within about 7 days of administration, as compared to baseline. In some embodiments, the method results in an increase in tendon strength of at least about 65% within about 7 days of administration, as compared to baseline. In some embodiments, the method results in an increase in tendon strength of at least about 70% within about 7 days of administration, as compared to baseline. In some embodiments, the method results in the tendon achieving at least about 80% of its final strength within about 7 days of administration, wherein final strength is measured at about 21 days after administration. In some embodiments, the method results in the tendon achieving at least about 85% of its final strength within about 7 days of administration, wherein final strength is measured at about 21 days after administration. In some embodiments, the method results in the tendon achieving at least about 90% of its final strength within about 7 days of administration, wherein final strength is measured at about 21 days after administration. In some embodiments, the method consists of administering to an affected site an effective amount of a composition consisting of a PDGF and a buffer.

In another aspect, provided herein is a composition for use in treating a tendinopathy, comprising an effective amount of a PDGF and a buffer. In some embodiments, the tendinopathy is a tendinosis. In some embodiments, the tendinopathy is a tendinitis. In some embodiments, the tendinopathy is a tenosynovitis. In some embodiments, the PDGF is selected from the group consisting of PDGF-AA, PDGF-BB, PDGF-AB, PDGF-CC, and PDGF-DD. In some embodiments, the PDGF is PDGF-BB. In some embodiments, the PDGF is recombinant human (rh) PDGF-BB. In some embodiments, the effective amount comprises between about 75 μg and about 7,500 μg of PDGF-BB per dose. In some embodiments, the effective amount comprises between about 500 μg to about 1,000 μg of PDGF-BB per dose. In some embodiments, the effective amount comprises between about 5,000 μg to about 7,500 μg of PDGF-BB per dose. In some embodiments, the effective amount comprises between about 450 μg to about 3000 μg of PDGF-BB per dose. In some embodiments, the effective amount comprises between about 400 μg to about 1000 μg of PDGF-BB per dose. In some embodiments, the effective amount comprises between about 500 μg to about 900 μg of PDGF-BB per dose. In some embodiments, the effective amount comprises between about 600 μg to about 800 μg of PDGF-BB per dose. In some embodiments, the effective amount comprises between about 650 μg to about 750 μg of PDGF-BB per dose. In some embodiments, the effective amount comprises about 700 μg of PDGF-BB per dose. In some embodiments, the composition has a volume of about 1.0 to about 2.0 ml per dose. In some embodiments, the composition has a volume of about 1.5 ml per dose. In some embodiments, the buffer is selected from the group consisting of phosphate-buffered saline ("PBS"), sodium acetate, ammonium acetate, acetic acid, citric acid, sodium citrate, tris(hydroxymethyl)aminoethane ("tris"), N-2-hydroxyethylpiperazine-N'-2-ethanesulfonic acid ("HEPES"), 3-(N-morpholino) propanesulfonic acid ("MOPS"), 2-(N-morpholino)ethanesulfonic acid ("MES"), N-(2-acetamido)iminodiacetic acid ("ADA"), piperazine-N, N'-bis(2-ethanesulfonic acid) ("PIPES"), and N-(2-acetamido)-2-aminoethanesulfonic acid ("ACES"). In some embodiments, the buffer is sodium acetate. In some embodiments, the sodium acetate is at a concentration between about 10 mM and about 100 mM. In some embodiments, the sodium acetate is at a concentration of about 20 mM. In some embodiments, the composition has a pH between about 4.0 and about 7.0. In some embodiments, the composition has pH of about 6. In some embodiments, the treating comprises administering the composition by direct injection to the affected site. In some embodiments, the affected site is an osseous-tendon junction. In some embodiments, the affected site is a tendon. In some embodiments, the tendinopathy is selected from the group consisting of Achilles tendinopathy, patellar tendinopathy, lateral epicondylitis, medial epicondylitis, plantar fasciitis, and rotator cuff tendinopathy. In some embodiments, the tendinopathy is lateral epicondylitis. In some embodiments, the composition is administered as a single dose. In some embodiments, the composition is administered by a single injection. In some embodiments, the composition is administered in more than one dose. In some embodiments, the composition is administered by a single injection once a week for four weeks. In some embodiments, the treating results in an increase in tendon strength of at least about 60% within about 7 days of administration, as compared to baseline. In some embodiments, the treating results in an increase in tendon strength of at least about 65% within about 7 days of administration, as compared to baseline. In some embodiments, the treating results in an increase in tendon strength of at least about 70% within about 7 days of administration, as compared to baseline. In some embodiments, the treating results in the tendon achieving at least about 80% of its final strength within about 7 days of administration, wherein final strength is measured at about 21 days after administration. In some embodiments, the treating results in the tendon achieving at least about 85% of its final strength within about 7 days of administration, wherein final strength is measured at about 21 days after administration. In some embodiments, the treating results in the tendon achieving at least about 90% of its final strength within about 7 days of administration, wherein final strength is measured at about 21 days after administration. In some embodiments, the composition consists of an effective amount of a PDGF and a buffer.

In another aspect, provided herein is the use of the PDGF compositions described herein in connection with the methods described herein, unless otherwise noted or as is clear from the specific context. The PDGF compositions described herein may also be used in the preparation of a medicament for use in the methods described herein.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** shows the effect of rhPDGF-BB treatment on tenocyte cell migration.

FIG. **2** shows the effect of rhPDGF-BB treatment on tenocyte cell proliferation as measured by BrdU incorporation.

FIG. **3** shows the injection site at the tendon-calcaneous junction in the right leg. Injections were performed with an insulin syringe using a 28.5 G needle.

FIG. **4** shows a representative image of a rat metatarsus-Achilles-gastrocnemius complex following processing of test animals for biomechanical testing.

FIG. **5** shows a representative image of a sagittal section from the lateral edge of the calcaneous (C)-Achilles tendon (T) attachment site.

FIG. **6**A shows the results of a dose response study on gross observational tendon growth for intra-tendon application of recombinant human platelet-derived growth factor, isoform BB ("rhPDGF-BB"), in the collagenase-induced rat Achilles tendon injury model seven days after treatment. A single injection of a medium (10.2 μg) or high (102 μg) dose of rhPDGF-BB produced a significant increase in tendon size seven days following rhPDGF-BB treatment.

FIG. **6**B shows the results of the same study twenty-one days following rhPDGF-BB treatment. The effect of a single injection of a high (102 μg) dose of rhPDGF-BB on tendon size was comparable to the effect of injection with sodium acetate buffer alone twenty-one days after treatment.

FIG. **7** is a different presentation of the same data as FIGS. **6**A and **6**B, showing the gross tendon size at 7- and 21-days post-rhPDGF-BB treatment (0=no growth to 3=severe growth).

FIG. **8** shows tendon width (μm±SEM) at the calcaneous insertion at 7- and 21-days post-rhPDGF-BB treatment.

FIG. **9** shows tendon width (μm±SEM) at the tendon body at 7- and 21-days post-rhPDGF-BB treatment.

FIG. **10** shows the effect of rhPDGF-BB on rate of cellular proliferation (cell counts±SEM) at 7- and 21-days post-rhPDGF-BB treatment.

FIG. **11** shows the mechanical properties of Achilles Tendons: maximum load to rupture (N±SEM) at 7- and 21-days post-rhPDGF-BB treatment.

FIG. **12** shows mean serum rhPDGF-BB concentration-time values following IV dosing.

FIG. **13** shows mean serum rhPDGF-BB concentration-time values following IT dosing.

FIG. **14**A shows the in vitro release profile for the amount of rhPDGF-BB released at each time point from 4-0 Vicryl sutures.

FIG. **14**B shows the in vitro cumulative release of rhPDGF-BB over 48 hours from 4-0 Vicryl sutures (mean±SEM).

FIG. **14**C shows the estimated in vivo cumulative dose of rhPDGF-BB versus initial rhPDGF-BB concentration in the suture coating solution.

FIG. **14**D shows the implanted 4-0 Vicryl suture lengths.

DETAILED DESCRIPTION

All references cited herein, including without limitation, patents, patent applications and scientific references, are hereby incorporated herein by reference in their entirety.

The compositions and methods of the invention surprisingly result in improved treatment of tendinopathies. In some embodiments, the compositions and methods of the invention result in increased strength of the tendon and an increased rate of tendon strength recovery. In some embodiments, the compositions and methods of the invention result in increased strength of the tendon. In some embodiments, the compositions and methods of the invention result in an increased rate of tendon strength recovery. For example, as a tendon heals after an injury, the biomechanical strength of the tendon increases as a process of tendon healing. Administration of a composition of the invention may result in a more rapid increase in tendon strength. Without wishing to be bound by theory, this more rapid increase in strength may be helpful in promoting healing of the tendon; provided the load bearing does not further increase the tendon injury, load bearing on a tendon generally improves the healing response of the tendon, as it generally results in improved tissue remodeling and reorganization. A faster initial increase in tendon strength (e.g. resulting from administration of a composition of the invention) may result in an ability to begin load bearing on the tendon more rapidly, thus further improving the tendon healing response. Without wishing to be bound by theory, the improvement in strength of the tendon may be caused by an increase in cellular proliferation and/or extracellular matrix production, and/or by an improvement in organization of the tissue (for example, an improvement in organization of the extracellular matrix).

Additionally, without wishing to be bound by theory, the inventors surprisingly discovered that when the compositions of the invention are administered directly into the tendon (e.g. by injection), the PDGF remains localized at the site of administration (e.g. at the site of injection). For example, as further detailed in Example 5 below, it was unexpected that administration of a composition consisting of PDGF in a buffer would result in PDGF remaining localized at the site of injection.

DEFINITIONS

As used herein, the term "treatment" refers to clinical intervention designed to alter the natural course of clinical pathology of the disorder being treated (e.g., a tendinopathy, such as tendinosis, tendinitis, or tenosynovitis). Desirable effects of treatment include, for example, one or more of decreasing pain or stiffness of the affected joint or limb, increasing mobility and strength of the affected joint or limb, decreasing the rate of tendinopathy progression, decreasing inflammation, increasing the strength of the tendon, improving the rate of tendon strength recovery, ameliorating or palliating the disease state, and remission or improved prognosis. An individual is successfully "treated," for example, if one or more symptoms associated with a tendinopathy are mitigated or eliminated.

As used herein, the term "effective amount" refers to at least an amount effective, at dosages and for periods of time necessary, to achieve the desired therapeutic or prophylactic result. An effective amount can be provided in one or more administrations.

Reference to "about" a value or parameter herein also includes (and describes) embodiments that are directed to that value or parameter per se.

As used herein and in the appended claims, the singular forms "a," "an," and "the" include plural reference unless the context clearly indicates otherwise. For example, reference to a "PDGF homodimer" is a reference to one or multiple PDGF homodimers, and includes equivalents thereof known to those skilled in the art, and so forth.

It is understood that all aspects and embodiments of the invention described herein include "comprising," "consisting," and "consisting essentially of" aspects and embodiments. It is to be understood that methods or compositions "consisting essentially of" the recited elements include only the specified steps or materials and those that do not materially affect the basic and novel characteristics of those methods and compositions (e.g., administering to an affected site an effective amount of a composition consisting essen-

tially of a PDGF and a buffer, or a composition consisting essentially of an effective amount of a PDGF in a buffered solution).

Platelet-Derived Growth Factor and Compositions Thereof

As used herein, the term "platelet-derived growth factor" or "PDGF" refers to any of four different isoforms of PDGF that activate cellular responses through two different receptors. Those isoforms include A (observed as a homodimer designated PDGF-AA and as part of a heterodimer with the β isoform designated PDGF-AB), B (observed as a homodomer designated PDGF-BB and as part of a heterodimer with the A isoform designated PDGF-AB), C (observed as a homodimer designated PDGF-CC) and D (observed as a homodimer designated PDGF-DD). Generally herein, the term "PDGF" refers generally to the known PDGF homo- and heterodimers (e.g., PDGF-AA, PDGF-BB, PDGF-AB, PDGF-CC, and PDGF-DD).

Provided herein are methods of treating tendinopathies in an individual and compositions for use in those methods. In general, the methods of treatment comprise administering a composition comprising PDGF to an affected site in an individual who has a tendinopathy. Specifically, the methods of treatment comprise administering a composition comprising PDGF and a buffer to the site of the tendinopathy. In some embodiments, the composition comprises a PDGF and a buffer (e.g., a buffered solution of PDGF).

In some embodiments, the compositions comprise a PDGF and a buffer. In some embodiments, the PDGF comprises a PDGF dimer selected from the group consisting of PDGF-AA, PDGF-BB, PDGF-AB, PDGF-CC, PDGF-DD, and mixtures and derivatives thereof. In some embodiments, the PDGF dimer is a homodimer. In some embodiments, the PDGF homodimer is selected from the group consisting of PDGF-AA, PDGF-BB, PDGF-CC, and PDGF-DD. In some embodiments, the PDGF homodimer is PDGF-BB. In some embodiments, the PDGF dimer is a heterodimer. In some embodiments, the PDGF heterodimer is PDGF-AB.

In some embodiments, PDGF can be obtained from natural sources. In some embodiments, PDGF can be produced by recombinant DNA techniques. In some embodiments, PDGF or fragments thereof may be produced using peptide synthesis techniques known to one of skill in the art, such as solid phase peptide synthesis.

When obtained from natural sources, PDGF can be derived from biological fluids. In some embodiments, the biological fluids can comprise any treated or untreated fluid associated with living organisms including blood. Biological fluids can also comprise blood components including platelet concentrate, apheresed platelets, platelet-rich plasma, plasma, serum, and fresh frozen plasma. Biological fluids can comprise platelets separated from plasma and resuspended in a physiological fluid or buffer.

When produced by recombinant DNA techniques, a DNA sequence encoding a single monomer (e.g., a PDGF B-chain or A-chain) can be inserted into cultured prokaryotic or eukaryotic cells for expression to subsequently produce the homodimer (e.g., PDGF-BB or PDGF-AA). In some embodiments, the PDGF comprises a PDGF homodimer (e.g., PDGF-AA, PDGF-BB, PDGF-CC, or PDGF-DD). In some embodiments, a PDGF heterodimer can be generated by inserting DNA sequences encoding for both monomeric units of the heterodimer into cultured prokaryotic or eukaryotic cells and allowing the translated monomeric units to be processed by the cells to produce the heterodimer (e.g., PDGF-AB). In some embodiments, the PDGF comprises a PDGF heterodimer (e.g., PDGF-AB). Commercially available recombinant human PDGF-BB may be obtained commercially from a variety of sources, including, but not limited to Leinco Technologies, Inc. (St. Louis, Mo.) and R&D Systems, Inc. (Minneapolis, Minn.).

In some embodiments described herein, the PDGF comprises a recombinant human PDGF ("rhPDGF"). In some embodiments, the recombinant human PDGF ("rhPDGF") is a PDGF dimer selected from the group consisting of rhPDGF-AA, rhPDGF-BB, rhPDGF-AB, rhPDGF-CC, rhPDGF-DD, and mixtures and derivatives thereof. In some embodiments, the recombinant human PDGF is an rhPDGF homodimer. In some embodiments, the recombinant human PDGF homodimer is selected from the group consisting of rhPDGF-AA, rhPDGF-BB, rhPDGF-CC, and rhPDGF-DD. In some embodiments, the recombinant human PDGF homodimer is rhPDGF-BB. In some embodiments, the recombinant human PDGF is an rhPDGF heterodimer. In some embodiments, the recombinant human PDGF heterodimer is rhPDGF-AB.

In some embodiments, PDGF-B comprises one or more of the following fragments: amino acids 1-31, 1-32, 33-108, 33-109, and/or 1-108 of the entire human B-chain. The complete amino acid sequence (amino acids 1-109) of the B-chain of human PDGF is provided in FIG. 15 of U.S. Pat. No. 5,516,896. It is to be understood that the PDGF-BB compositions of the present invention may comprise a combination of intact humanPDGF-B (amino acids 1-109) and fragments thereof. Other fragments of PDGF may be employed such as those disclosed in U.S. Pat. No. 5,516,896. In some embodiments, the PDGF-BB comprises at least 65% of full-length human PDGF-B (amino acids 1-109). In some embodiments, the PDGF-BB comprises at least 75%, 80%, 85%, 90%, 95%, or 99% of full-length human PDGF-B (amino acid 1-109).

In some embodiments, the composition comprises a PDGF dimer (e.g., an rhPDGF dimer) selected from the group consisting of PDGF-AA, PDGF-BB, PDGF-AB, PDGF-CC, and PDGF-DD, and the composition comprises a PDGF dimer at a concentration ranging from about 0.01 mg/ml to about 10.0 mg/ml, from about 0.05 mg/ml to about 5.0 mg/ml, from about 0.1 mg/ml to about 1.0 mg/ml, or from about 0.1 mg/ml to about 2.0 mg/ml, from about 0.1 mg/ml to about 3.0 mg/ml, from about 0.1 mg/ml to about 4.0 mg/ml, about 0.1 mg/ml to about 0.4 mg/ml, from about 0.1 mg/ml to about 5.0 mg/ml, about 0.9 mg/ml to about 1.5 mg/ml. In some embodiments, the composition comprises a PDGF dimer at a concentration of about 3.4 mg/ml. In some embodiments, the composition comprises a PDGF dimer at a concentration of about 1.0 mg/ml. In some embodiments, the composition comprises a PDGF dimer at a concentration of about 0.34 mg/ml. In some embodiments, the composition comprises a PDGF dimer at any one of the following concentrations: about 0.05 mg/ml; about 0.1 mg/ml; about 0.15 mg/ml; about 0.2 mg/ml; about 0.25 mg/ml; about 0.3 mg/ml; about 0.35 mg/ml; about 0.4 mg/ml; about 0.45 mg/ml; about 0.5 mg/ml, about 0.55 mg/ml, about 0.6 mg/ml, about 0.65 mg/ml, about 0.7 mg/ml; about 0.75 mg/ml; about 0.8 mg/ml; about 0.85 mg/ml; about 0.9 mg/ml; about 0.95 mg/ml; about 1.0 mg/ml; about 1.5 mg/ml; about 2.0 mg/ml; about 2.5 mg/ml; about 3.0 mg/ml; about 3.5 mg/ml; about 4.0 mg/ml; about 4.5 mg/ml; or about 5.0 mg/ml. It is to be understood that these concentrations are simply examples of particular embodiments, and that the concentration of PDGF dimer may be within any of the concentration ranges stated above.

In some embodiments, the PDGF dimer (e.g., an rhPDGF dimer) is PDGF-BB. In some embodiments, the composition

comprises PDGF-BB at a concentration ranging from about 0.01 mg/ml to about 10.0 mg/ml, from about 0.05 mg/ml to about 5.0 mg/ml, from about 0.1 mg/ml to about 1.0 mg/ml, or from about 0.1 mg/ml to about 2.0 mg/ml, from about 0.1 mg/ml to about 3.0 mg/ml, from about 0.1 mg/ml to about 4.0 mg/ml, from about 0.1 mg/ml to about 5.0 mg/ml, about 0.1 mg/ml to about 0.4 mg/ml, about 0.9 mg/ml to about 1.5 mg/ml. In some embodiments, the composition comprises PDGF-BB at a concentration of about 3.4 mg/ml. In some embodiments, the composition comprises PDGF-BB at a concentration of about 1.0 mg/ml. In some embodiments, the composition comprises PDGF-BB at a concentration of about 0.34 mg/ml. In some embodiments, the composition comprises PDGF-BB at any one of the following concentrations: about 0.05 mg/ml; about 0.1 mg/ml; about 0.15 mg/ml; about 0.2 mg/ml; about 0.25 mg/ml; about 0.3 mg/ml; about 0.35 mg/ml; about 0.4 mg/ml; about 0.45 mg/ml; about 0.5 mg/ml, about 0.55 mg/ml, about 0.6 mg/ml, about 0.65 mg/ml, about 0.7 mg/ml; about 0.75 mg/ml; about 0.8 mg/ml; about 0.85 mg/ml; about 0.9 mg/ml; about 0.95 mg/ml; about 1.0 mg/ml; about 1.5 mg/ml; about 2.0 mg/ml; about 2.5 mg/ml; about 3.0 mg/ml; about 3.5 mg/ml; about 4.0 mg/ml; about 4.5 mg/ml; or about 5.0 mg/ml. It is to be understood that these concentrations are simply examples of particular embodiments, and that the concentration of rhPDGF-BB may be within any of the concentration ranges stated above.

In some embodiments, the PDGF is selected from the group consisting of PDGF-AA, PDGF-BB, PDGF-AB, PDGF-CC, and PDGF-DD. Various amounts of PDGF may be used in the compositions of the present invention. Amounts of PDGF that can be used include, but are not limited to, amounts in the following ranges: about 1 μg to about 50 mg, about 10 μg to about 25 mg, about 100 μg to about 10 mg, about 250 μg to about 5 mg, and about 450 μg to about 3 mg. In some embodiments, the PDGF is PDGF-BB. Various amounts of PDGF-BB may be used in the compositions of the present invention. Amounts of PDGF-BB that can be used include, but are not limited to, amounts in the following ranges: about 1 μg to about 50 mg, about 10 μg to about 25 mg, about 100 μg to about 10 mg, about 250 μg to about 5 mg and about 450 μg to about 3 mg.

The concentration of PDGF (e.g., rhPDGF), including PDGF-AA, PDGF-BB, PDGF-AB, PDGF-CC, and PDGF-DD, in some embodiments of the present invention can be determined, for example, by using an enzyme-linked immunoassay as described in U.S. Pat. Nos. 6,221,625; 5,747,273; and 5,290,708, or any other assay known in the art for determining PDGF concentration. When provided herein, the molar concentration of rhPDGF is determined based on the molecular weight of a PDGF homodimer (e.g., PDGF-BB, MW~25 kDa).

In some embodiments of the present invention, the PDGF (e.g., rhPDGF) can be in a highly purified form. Purified PDGF, as used herein, comprises compositions having greater than about 95% by weight PDGF prior to incorporation in solutions of the present invention. The solution may be prepared using any pharmaceutically acceptable buffer or diluent. In some embodiments, the PDGF can be substantially purified. Substantially purified PDGF, as used herein, comprises compositions having about 5% to about 95% by weight PDGF prior to incorporation into solutions of the present invention. In one embodiment, substantially purified PDGF comprises compositions having about 65% to about 95% by weight PDGF prior to incorporation into solutions of the present invention. In some embodiments, substantially purified PDGF comprises compositions having about 70% to about 95%, about 75% to about 95%, about 80% to about 95%, about 85% to about 95%, or about 90% to about 95%, by weight PDGF, prior to incorporation into solutions of the present invention. Purified PDGF and substantially purified PDGF may be incorporated into the compositions.

In a further embodiment, the PDGF can be partially purified. Partially purified PDGF, as used herein, comprises compositions having PDGF in the context of platelet-rich plasma, fresh frozen plasma, or any other blood product that requires collection and separation to produce PDGF. Embodiments of the present invention contemplate that any of the PDGF isoforms provided herein, including homodimers and heterodimers, can be purified or partially purified. Compositions of the present invention comprising PDGF mixtures may comprise PDGF isoforms or PDGF fragments in partially purified proportions. Partially purified and purified PDGF, In some embodiments, can be prepared as described in U.S. application Ser. No. 11/159,533 (U.S. Patent Publication No. 2006/0084602 A1).

In any of the embodiments described herein, the highly purified or partially purified PDGF is selected from the group consisting of PDGF-AA, PDGF-BB, PDGF-AB, PDGF-CC, and PDGF-DD. In any of the embodiments described herein, the highly purified or partially purified PDGF is PDGF-BB.

Buffers

In some embodiments, the compositions comprise a PDGF and a buffer, preferably a pharmaceutically acceptable buffer. Buffers suitable for use in PDGF solutions of the present invention can comprise, but are not limited to, carbonates, phosphates (e.g., phosphate-buffered saline), saline, histidine, acetates (e.g., sodium acetate or ammonium acetate), acidic buffers such as acetic acid, citric acid, sodium citrate and HCl, and organic buffers such as lysine, Tris buffers (e.g., tris(hydroxymethyl)aminoethane), N-2-hydroxyethylpiperazine-N'-2-ethanesulfonic acid (HEPES), 3-(N-morpholino) propanesulfonic acid (MOPS), 2-(N-morpholino)ethanesulfonic acid (MES), N-(2-acetamido)iminodiacetic acid ("ADA"), piperazine-N,N'-bis(2-ethanesulfonic acid) (PIPES), and N-(2-acetamido)-2-aminoethanesulfonic acid (ACES).

Buffers can be selected based on biocompatibility with PDGF and the buffer's ability to impede undesirable protein modification. Buffers can additionally be selected based on compatibility with host tissues and pharmaceutical acceptability. In some embodiments, the PDGF compositions comprise PDGF in sodium acetate buffer. In some embodiments, the PDGF in sodium acetate buffer is selected from the group consisting of PDGF-AA, PDGF-BB, PDGF-AB, PDGF-CC, and PDGF-DD. In some embodiments, the PDGF in sodium acetate buffer is rhPDGF-BB.

The buffers may be employed at different molarities, for example between about 0.1 mM to about 100 mM, about 1 mM to about 100 mM, about 10 mM to about 100 mM, about 1 mM to about 50 mM, about 5 mM to about 40 mM, about 10 mM to about 30 mM, or about 15 mM to about 25 mM, or any molarity within these ranges. In some embodiments, an acetate buffer is employed at a molarity of about 20 mM. The buffers may be employed at different concentrations, for example, between about 0.01 mg/ml to about 10 mg/ml, 0.05 mg/ml to about 5 mg/ml, about 0.5 mg/ml to about 5 mg/ml, 0.1 mg/ml to about 1 mg/ml, and about 0.5 mg/ml to about 1 mg/ml, or any concentration within these ranges.

In another embodiment, solutions comprising PDGF may be formed by solubilizing lyophilized PDGF in water, wherein prior to solubilization the PDGF is lyophilized from an appropriate buffer.

Compositions comprising PDGF and a buffer according to some embodiments of the present invention can have a pH ranging from about 3.0 to about 8.0 or from about 4.0 to about 7.0. In some embodiments, the composition comprising PDGF and a buffer has a pH ranging from about 5.0 to about 8.0, more preferably about 5.5 to about 7.0, most preferably about 5.5 to about 6.5, or any value within these ranges. In some embodiments described herein, the PDGF composition is at a pH between about 4.0 and about 7.0. In some embodiments described herein, the PDGF composition is at a pH between about 5.0 and about 7.0. In some embodiments described herein, the PDGF composition is at a pH of about 4.0, about 5.0, about 6.0, or about 7.0. The pH of compositions comprising PDGF and a buffer, in some embodiments, can be compatible with the prolonged stability and efficacy of PDGF or any other desired biologically active agent. PDGF is generally more stable in an acidic environment. Therefore, in accord with some embodiments, provided herein is an acidic storage formulation of a PDGF composition. In accord with some embodiments, the composition comprising PDGF and a buffer preferably has a pH from about 3.0 to about 7.0, and more preferably from about 4.0 to about 6.5. The biological activity of PDGF, however, can be optimized in a solution having a neutral pH range. Therefore, in some embodiments, provided herein is a neutral pH formulation of a composition comprising PDGF and a buffer. In accord with this embodiment, the composition preferably has a pH from about 5.0 to about 8.0, more preferably about 5.5 to about 7.0, most preferably about 5.5 to about 6.5.

The pH of solutions comprising PDGF, in some embodiments, can be controlled by the buffers recited herein. Various proteins demonstrate different pH ranges in which they are stable. Protein stabilities are primarily reflected by isoelectric points and charges on the proteins. The pH range can affect the conformational structure of a protein and the susceptibility of a protein to proteolytic degradation, hydrolysis, oxidation, and other processes that can result in modification to the structure and/or biological activity of the protein.

In some embodiments, the PDGF compositions provided herein comprise a PDGF selected from the group consisting of PDGF-AA, PDGF-BB, PDGF-CC, PDGF-DD, and PDGF-AB and a buffer selected from the group consisting of PBS, sodium acetate, ammonium acetate, acetic acid, citric acid, sodium citrate, tris(hydroxymethyl)aminoethane, HEPES, MOPS, MES, ADA, PIPES, and ACES. In some embodiments, the PDGF compositions provided herein comprise rhPDGF-BB and a buffer selected from the group consisting of PBS, sodium acetate, ammonium acetate, acetic acid, citric acid, sodium citrate, tris(hydroxymethyl) aminoethane, HEPES, MOPS, MES, ADA, PIPES, and ACES. In some embodiments, the PDGF composition comprises rhPDGF-BB and PBS. In some embodiments, the PDGF composition comprises rhPDGF-BB and sodium acetate. In some embodiments, the PDGF composition comprises rhPDGF-BB and ammonium acetate. In some embodiments, the PDGF composition comprises rhPDGF-BB and acetic acid. In some embodiments, the PDGF composition comprises rhPDGF-BB and citric acid. In some embodiments, the PDGF composition comprises rhPDGF-BB and sodium citrate. In some embodiments, the PDGF composition comprises rhPDGF-BB and tris(hydroxymethyl)aminoethane. In some embodiments, the rhPDGF composition comprises PDGF-BB and HEPES. In some embodiments, the PDGF composition comprises rhPDGF-BB and MOPS. In some embodiments, the PDGF composition comprises rhPDGF-BB and MES. In some embodiments, the PDGF composition comprises rhPDGF-BB and ADA. In some embodiments, the PDGF composition comprises rhPDGF-BB and PIPES. In some embodiments, the PDGF composition comprises rhPDGF-BB and ACES.

In some embodiments described herein, the buffer is at a concentration between 1 mM and 1000 mM. In some embodiments described herein, the buffer is at a concentration between 10 mM and 1000 mM. In some embodiments described herein, the buffer is at a concentration between 100 mM and 1000 mM. In some embodiments described herein, the buffer is at a concentration between 5 mM and 500 mM. In some embodiments described herein, the buffer is at a concentration between 50 mM and 500 mM. In some embodiments described herein, the buffer is at a concentration between 10 mM and 100 mM. In some embodiments described herein, the buffer is at a concentration between 20 mM and 200 mM. In some embodiments described herein, the buffer is at a concentration of 10 mM, 20 mM, 30 mM, 40 mM, 50 mM, 60 mM, 70 mM, 80 mM, 90 mM or 100 mM.

In some embodiments, the PDGF composition comprises rhPDGF-AA and 20 mM sodium acetate at about pH=6.0. In some embodiments, the PDGF composition comprises rhPDGF-AB and 20 mM sodium acetate at about pH=6.0. In some embodiments, the PDGF composition comprises rhPDGF-BB and 20 mM sodium acetate at about pH=6.0. In some embodiments, the PDGF composition comprises rhPDGF-CC and 20 mM sodium acetate at about pH=6.0. In some embodiments, the PDGF composition comprises rhPDGF-DD and 20 mM sodium acetate at about pH=6.0.

Doses and Dosing Regimens

Effective doses of PDGF identified in a rat tendon model may be extrapolated to effective amounts for other individuals, such as humans, based on the relative size of treatment area of the tendon. For example, the treatment area of a human Achilles tendon is approximately 69 times larger than the treatment area of a rat Achilles tendon, so an effective amount or dose of a PDGF for a human patient may be approximately 69 times the effective amount or dose of a PDGF determined in the rat tendon model.

Exemplary effective amounts or doses delivered by administration of the PDGF compositions provided herein include, but are not limited to, about 450 μg to about 3,000 μg per dose, about 1 μg to about 10,000 μg per dose, including for example any of about 1 μg to about 7,500 μg per dose, about 1 μg to about 5,000 μg per dose, about 1 μg to about 2,500 μg per dose, about 1 μg to about 1,000 μg per dose, about 1 μg to about 500 μg per dose, about 1 μg to about 250 μg per dose, about 1 μg to about 100 μg per dose, about 10 μg to about 10,000 μg per dose, about 10 μg to about 7,500 μg per dose, about 10 μg to about 5,000 μg per dose, about 10 μg to about 2,500 μg per dose, about 10 μg to about 1,000 μg per dose, about 10 μg to about 500 μg per dose, about 10 μg to about 250 μg per dose, about 10 μg to about 100 μg per dose, about 25 μg to about 10,000 μg per dose, about 25 μg to about 7,500 μg per dose, about 25 μg to about 5,000 μg per dose, about 25 μg to about 2,500 μg per dose, about 25 μg to about 1,000 μg per dose, about 25 μg to about 500 μg per dose, about 25 μg to about 250 μg per dose, about 25 μg to about 100 μg per dose, about 50 μg to about 10,000 μg per dose, about 50 μg to about 7,500 μg per dose, about 50 μg to about 5,000 μg per dose, about 50 μg

to about 2,500 μg per dose, about 50 μg to about 1,000 μg per dose, about 50 μg to about 500 μg per dose, about 50 μg to about 250 μg per dose, about 50 μg to about 100 μg per dose, about 50 μg to about 100 μg per dose, about 75 μg to about 10,000 μg per dose, about 75 μg to about 7,500 μg per dose, about 75 μg to about 5,000 μg per dose, about 75 μg to about 2,500 μg per dose, about 75 μg to about 1,000 μg per dose, about 75 μg to about 500 μg per dose, about 75 μg to about 250 μg per dose, about 75 μg to about 125 μg per dose, about 100 μg to about 200 μg per dose, about 200 μg to about 300 μg per dose, about 300 μg to about 500 μg per dose, about 500 μg to about 1,000 μg per dose, about 1,000 μg to about 2,500 μg per dose, about 1,000 μg to about 5,000 μg per dose, about 1,000 μg to about 7,500 μg per dose, about 1,000 μg to about 10,000 μg per dose, about 2,500 μg to about 5,000 μg per dose, about 2,500 μg to about 7,500 μg per dose, about 5,000 μg to about 7,500 μg per dose, about 10,000 μg to about 50,000 μg per dose, about 50,000 μg to about 100,000 μg per dose, about 100,000 μg to about 200,000 μg per dose, about 200,000 μg to about 300,000 μg per dose, about 300,000 μg to about 400,000 μg per dose, or about 400,000 μg to about 500,000 μg per dose.

In some embodiments, the PDGF is administered at about 400 μg to about 1000 μg per dose, about 500 μg to about 900 μg per dose, about 600 μg to about 800 μg, about 650 μg to about 750 μg per dose, about 700 μg per dose.

In some embodiments, the doses provided herein are administered in a volume of 50 μL, 100 μL, 150 μL, 200 μL, 250 μL, 300 μL, 350 μL, 400 μL, 450 μL, 500 μL, 550 μL, 600 μL, 650 μL, 700 μL, 750 μL, 800 μL, 850 μL, 900 μL, 950 μL, 1000 μL or more. In some embodiments, the doses provided herein are administered in a volume of 100 μL, 200 μL, 300 μL, 400 μL, 500 μL, 600 μL, 700 μL, 800 μL, 900 μL, 1000 μL, 1100 μL, 1200 μL, 1300 μL, 1400 μL, 1500 μL, 1600 μL, 1700 μL, 1800 μL, 1900 μL, 2000 μL or more. In some embodiments, the doses provided herein are administered in a volume of about 1000 μL to about 2000 μL, about 125 μL to about 1750 μL, about 1300 μL to about 1600 μL, or about 1500 μL.

The PDGF compositions provided herein may be administered in a single daily dose, or the total daily dose may be administered in divided dosages of, e.g., two, three, or four times daily. In some embodiments, a single daily dose of the PDGF compositions provided herein can be administered once a day for 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, or more days. The PDGF compositions can also be administered less frequently than daily, for example, six times a week, five times a week, four times a week, three times a week, twice a week, once a week, once every two weeks, once every three weeks, once a month, once every two months, once every three months, once every four months, once every five months, or once every six months.

In some embodiments, the PDGF compositions are administered at intervals over a period of time. In some embodiments, the PDGF compositions are administered once a week for one, two, three, four, five, six or more months. In some embodiments, the PDGF compositions are administered twice a month for one, two, three, four, five, six or more months. In some embodiments, the PDGF compositions are administered monthly for one, two, three, four, five, six or more months.

Methods of Treating Tendinopathies

As used herein, the term "tendinopathy" refers to chronic tendon injuries such as tendinosis, tendinitis, and tenosynovitis. Exemplary tendinopathies include, but are not limited to, Achilles tendinopathy, patellar tendinopathy, lateral epicondylitis, or "tennis elbow," medial epicondylitis, plantar fasciitis, and rotator cuff tendinopathy.

As used herein, the term "tendinosis" refers to a non-inflammatory injury to the tendon characterized by intratendinous degeneration of the tendon usually in the form of microtears in the tissue in and around the tendon caused by overuse, leading to an increase in the number of tendon repair cells around the area of damage. Degeneration of the tendon is caused by damage to or disorganization of the collagen fibers, cells, and vascular components of the tendon, which can reduce the tendon's tensile strength and can lead to tendon rupture if not treated. In some cases, tendinosis is accompanied by focal necrosis or calcification of the tendon.

As used herein, the term "tendinitis" refers to an inflammatory injury to the tendon, characterized by degeneration like that observed in tendinosis, but also accompanied by inflammation of the tendon, vascular disruption and an inflammatory repair response. Tendinitis is often associated with fibroblastic and myofibroblastic proliferation, as well as hemorrhage and organizing granulation tissue. Generally tendinitis is referred to by the body part involved, such as Achilles tendinitis (affecting the Achilles tendon), or patellar tendinitis (also known as "jumper's knee," affecting the patellar tendon), though there are certain exceptions, such as lateral epicondylitis (also known as "tennis elbow," affecting the Extensor Carpi Radialis Brevis tendon).

Tendinopathies which may be treated by the methods of the invention include tendinopathies of any tendon in the human or mammalian body. In some embodiments, the tendinopathy is tendinosis. In some embodiments, the tendinopathy is tendinitis. In some embodiments, the tendinopathy is tenosynovitis.

Tendons which may be treated by the methods of the invention include any tendon of the human or mammalian body. Non-limiting examples of tendons include the patellar tendon, the anterior tibialis tendon, the Achilles tendon, the hamstring tendon, the semitendinosus tendon, the gracilis tendon, the abductor tendon, the adductor tendon, the supraspinatus tendon, the infraspinatus tendon, the subscapularis tendon, the teres minor tendon, the flexor tendon, the rectus femoris tendon, the tibialis posterior tendon, and the quadriceps femoris tendon.

In some embodiments, the tendon is a tendon of the foot or ankle. In some embodiments, the tendon of the foot or ankle is selected from the group consisting of the extensor hallucis longus, the flexor hallucis longus, the extensor digitorum longus, the extensor digitorum brevis, the peroneus longus, the peroneus brevis, the flexor hallucis brevis, the flexor digitorum longus, the posterior tibialis, the Achilles tendon, and the plantar fascia.

In some embodiments, the tendon is a tendon of the leg. In some embodiments, the tendon of the leg is selected from the group consisting of the patellar tendon, the anterior tibialis tendon, the Achilles tendon, the hamstring tendon, the semitendinosus tendon, the gracilis tendon, the abductor tendon, and the adductor tendon. In some embodiments, the tendon is selected from the group consisting of the flexor tendon, the rectus femoris tendon, the tibialis posterior tendon, and the quadriceps femoris tendon.

In some embodiments, the tendon is a tendon of the shoulder. In some embodiments, the tendon of the shoulder is selected from the group consisting of the supraspinatus tendon, the infraspinatus tendon, the subscapularis tendon, and the teres minor tendon (rotator cuff complex).

In some embodiments, the tendon is a tendon of the elbow. In some embodiments, the tendon of the elbow is

selected from the group consisting of the biceps tendon, the triceps tendon, the extensor carpi radialis brevis, the common extensor tendon, the extensor digitorum, the extensor digiti minimi, the extensor carpi ulnaris, the supinator, the common flexor tendon, the pronator teres, the flexor carpi radialis, the palmaris longus, the flexor carpi ulnaris and the digitorum superficialis. In some embodiments, the tendon is a tendon of the wrist. In some embodiments, the tendon of the wrist is selected from the group consisting of biceps tendon, the triceps tendon, the extensor carpi radialis brevis, the common extensor tendon, the extensor digitorum, the extensor digiti minimi, the extensor carpi ulnaris, the supinator, the common flexor tendon, the pronator teres, the flexor carpi radialis, the palmaris longus, the flexor carpi ulnaris, the digitorum superficialis, the flexor pollicis brevis, the flexor pollicis longus, the abductor pollicis brevis, the abductor pollicis longus, the flexor digitorum profundus, the flexor digitorum superficialis, the extensor pollicis brevis, and the extensor pollicis longus. In some embodiments, the tendon is a tendon of the hand. In some embodiments, the tendon of the hand is selected from the group consisting of the flexor pollicis brevis, the flexor pollicis longus, the abductor pollicis brevis, the abductor pollicis longus, the flexor digitorum profundus, the flexor digitorum superficialis, the extensor pollicis brevis, and the extensor pollicis longus.

In some embodiments, the tendinopathy is rotator cuff tendinopathy. In some embodiments, the rotator cuff tendinopathy is selected from the group consisting of supraspinatus tendinopathy, infraspinatus tendinopathy, subscapularis tendinopathy, and teres minor tendinopathy.

In some embodiments, the tendinopathy is lateral epicondylitis or "tennis elbow" at the extensor muscle group origin at the lateral humeral condyle insertion, principally in the extensor carpi radialis brevis (ECRB) tendon. In some embodiments, the subject having lateral epicondylitis has associated pain (e.g. for at least about six months) as evidenced by pain reported to be ≥50 on a Visual Analog Score (VAS). In some embodiments, the subject having lateral epicondylitis has associated pain that increases with pressure on the lateral epicondyle and/or resisted extension of the wrist, e.g. for at least about six months. In some embodiments, the tendinopathy is medial epicondylitis or "golfer's elbow" at the interface between the pronator teres and flexor carpi radialis origin of the medial humeral condyle.

In some embodiments, the tendinopathy is patellar tendinopathy. In some embodiments, the tendinopathy is Achilles tendinopathy. In some embodiments, the tendinopathy is plantar fasciitis. In some embodiments, the tendinopathy is medial plantar fasciitis. In some embodiments, the tendinopathy is lateral plantar fasciitis.

In another aspect, provided herein are methods of treating tendinopathies comprising administering an effective amount of a composition comprising PDGF and a buffer to an affected site. In some embodiments, the PDGF is selected from the group consisting of PDGF-AA, PDGF-BB, PDGF-AB, PDGF-CC, and PDGF-DD. In some embodiments, the PDGF is PDGF-BB. In some embodiments, the effective amount of the composition comprises between about 75 μg and about 7,500 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises between about 500 μg to about 1,000 μg of PDGF-BB per dose. In some embodiments, the effective amount of the composition comprises between about 450 μg to about 3,000 μg of PDGF per dose. In some embodiments, the effective amount of the composition comprises between about 5,000 μg to about 7,500 μg of PDGF-BB per dose.

In some embodiments, the buffer is selected from the group consisting of phosphate-buffered saline ("PBS"), sodium acetate, ammonium acetate, acetic acid, citric acid, sodium citrate, tris(hydroxymethyl)aminoethane ("tris"), N-2-hydroxyethylpiperazine-N'-2-ethanesulfonic acid ("HEPES"), 3-(N-morpholino) propanesulfonic acid ("MOPS"), 2-(N-morpholino)ethanesulfonic acid ("MES"), N-(2-acetamido)iminodiacetic acid ("ADA"), piperazine-N, N'-bis(2-ethanesulfonic acid) ("PIPES"), and N-(2-acetamido)-2-aminoethanesulfonic acid ("ACES"). In some embodiments, the buffer is sodium acetate. In some embodiments, the sodium acetate is at a concentration between about 10 mM and about 100 mM. In some embodiments, the sodium acetate is at a concentration of about 20 mM. In some embodiments, the sodium acetate is at a pH between about 4.0 and about 7.0. In some embodiments, the sodium acetate is at about pH 6.

In some embodiments, the administering is by direct injection to the affected site. In some embodiments, the direct injection is accomplished using the "peppering technique" with or without ultrasound guidance. The "peppering technique" is an injection method whereby after the needle is inserted into the tender area, multiple small injections are performed by withdrawing, redirecting and reinserting the needle without emerging from the skin.

In some embodiments, the affected site is an osseous-tendon junction. In some embodiments, the affected site is a tendon. In some embodiments, the tendinopathy is selected from the group consisting of Achilles tendinopathy, patellar tendinopathy, lateral epicondylitis, medial epicondylitis, plantar fasciitis, and rotator cuff tendinopathy. In some embodiments, the composition is administered by a single injection. In some embodiments, the composition is administered by a single injection once a week for four weeks.

In some embodiments, the tendinopathy is tendinosis. In some embodiments, the tendinosis is selected from the group consisting of extensor hallucis longus tendinosis, flexor hallucis longus tendinosis, extensor digitorum longus tendinosis, extensor digitorum brevis tendinosis, peroneus longus tendinosis, peroneus brevis tendinosis, flexor hallucis brevis tendinosis, flexor digitorum longus tendinosis, posterior tibialis tendinosis, Achilles tendon tendinosis, and plantar fascia tendinosis. In some embodiments, the tendinosis is selected from the group consisting of patellar tendinosis, the anterior tibialis tendinosis, the hamstring tendinosis, semitendinosus tendinosis, gracilis tendinosis, abductor tendinosis, and adductor tendinosis. In some embodiments, the tendinosis is selected from the group consisting of flexor tendinosis, rectus femoris tendinosis, tibialis posterior tendinosis, and quadriceps femoris tendinosis. In some embodiments, the tendinosis is selected from the group consisting of supraspinatus tendinosis, infraspinatus tendinosis, subscapularis tendinosis, and teres minor tendinosis.

In some embodiments, the tendinosis is selected from the group consisting of biceps tendinosis, triceps tendinosis, extensor carpi radialis brevis tendinosis, common extensor tendinosis, extensor digitorum tendinosis, extensor digiti minimi tendinosis, extensor carpi ulnaris tendinosis, supinator tendinosis, common flexor tendinosis, pronator teres tendinosis, flexor carpi radialis tendinosis, palmaris longus tendinosis, flexor carpi ulnaris tendinosis and digitorum superficialis tendinosis. In some embodiments, the tendinosis is selected from the group consisting of biceps tendinosis, triceps tendinosis, extensor carpi radialis brevis tendinosis,

common extensor tendinosis, extensor digitorum tendinosis, extensor digiti minimi tendinosis, extensor carpi ulnaris tendinosis, supinator tendinosis, common flexor tendinosis, pronator teres tendinosis, flexor carpi radialis tendinosis, palmaris longus tendinosis, flexor carpi ulnaris tendinosis, digitorum superficialis tendinosis, flexor pollicis brevis tendinosis, flexor pollicis longus tendinosis, abductor pollicis brevis tendinosis, abductor pollicis longus tendinosis, flexor digitorum profundus tendinosis, flexor digitorum superficialis tendinosis, extensor pollicis brevis tendinosis, and extensor pollicis longus tendinosis. In some embodiments, the tendinosis is selected from the group consisting of flexor pollicis brevis tendinosis, flexor pollicis longus tendinosis, abductor pollicis brevis tendinosis, abductor pollicis longus tendinosis, flexor digitorum profundus tendinosis, flexor digitorum superficialis tendinosis, extensor pollicis brevis tendinosis, and extensor pollicis longus tendinosis.

In some embodiments, the tendinopathy is tendinitis. In some embodiments, the tendinitis is selected from the group consisting of extensor hallucis longus tendinitis, flexor hallucis longus tendinitis, extensor digitorum longus tendinitis, extensor digitorum brevis tendinitis, peroneus longus tendinitis, peroneus brevis tendinitis, flexor hallucis brevis tendinitis, flexor digitorum longus tendinitis, posterior tibialis tendinitis, Achilles tendon tendinitis, and plantar fascia tendinitis. In some embodiments, the tendinitis is selected from the group consisting of patellar tendinitis, the anterior tibialis tendinitis, the hamstring tendinitis, semitendinosus tendinitis, gracilis tendinitis, abductor tendinitis, and adductor tendinitis. In some embodiments, the tendinitis is selected from the group consisting of flexor tendinitis, rectus femoris tendinitis, tibialis posterior tendinitis, and quadriceps femoris tendinitis. In some embodiments, the tendinitis is selected from the group consisting of supraspinatus tendinitis, infraspinatus tendinitis, subscapularis tendinitis, and teres minor tendinitis.

In some embodiments, the tendinitis is selected from the group consisting of biceps tendinitis, triceps tendinitis, extensor carpi radialis brevis tendinitis, common extensor tendinitis, extensor digitorum tendinitis, extensor digiti minimi tendinitis, extensor carpi ulnaris tendinitis, supinator tendinitis, common flexor tendinitis, pronator teres tendinitis, flexor carpi radialis tendinitis, palmaris longus tendinitis, flexor carpi ulnaris tendinitis and digitorum superficialis tendinitis. In some embodiments, the tendinitis is selected from the group consisting of biceps tendinitis, triceps tendinitis, extensor carpi radialis brevis tendinitis, common extensor tendinitis, extensor digitorum tendinitis, extensor digiti minimi tendinitis, extensor carpi ulnaris tendinitis, supinator tendinitis, common flexor tendinitis, pronator teres tendinitis, flexor carpi radialis tendinitis, palmaris longus tendinitis, flexor carpi ulnaris tendinitis, digitorum superficialis tendinitis, flexor pollicis brevis tendinitis, flexor pollicis longus tendinitis, abductor pollicis brevis tendinitis, abductor pollicis longus tendinitis, flexor digitorum profundus tendinitis, flexor digitorum superficialis tendinitis, extensor pollicis brevis tendinitis, and extensor pollicis longus tendinitis. In some embodiments, the tendinitis is selected from the group consisting of flexor pollicis brevis tendinitis, flexor pollicis longus tendinitis, abductor pollicis brevis tendinitis, abductor pollicis longus tendinitis, flexor digitorum profundus tendinitis, flexor digitorum superficialis tendinitis, extensor pollicis brevis tendinitis, and extensor pollicis longus tendinitis.

The methods of the invention may result in improvement in one or more of the following: decreasing pain of the affected joint or limb, decreasing stiffness of the affected joint or limb, increasing mobility of the affected joint or limb, increasing strength of the affected joint or limb, decreasing the rate of tendinopathy progression, decreasing inflammation, increasing the strength of the tendon, or improving the rate of tendon strength recovery. Various methods for measuring effectiveness of the treatment include, but are not limited to: Disabilities of the Arm, Shoulder and Hand Score (DASH), Visual Analog Score (VAS), and grip strength testing. In some embodiments, the treatment results in at least a 25% reduction in pretreatment score for DASH. In some embodiments, the treatment results in at least a 25% reduction in pretreatment score for VAS. In some embodiments, the treatment produces a decrease in pain with applied pressure and/or joint flexion. In some embodiments, the treatment produces a decrease in pain with applied pressure and/or joint flexion and an increase in joint mobility. In some embodiments, the treatment does not result in any abnormal bone growth. In some embodiments, the treatment does not result in any abnormal tendon growth. In some embodiments, the treatment is safe and tolerated by the subject. In some embodiments, safety and tolerability of the composition is evaluated by the lack of an adverse event or an abnormality identified by one or more of the following: physical examination, vital sign measurement, laboratory test, x-ray, and/or MRI imaging.

In some embodiments, the treatment results in increased strength of the tendon. In some embodiments, the treatment results in a more rapid rate of tendon strength recovery. In some embodiments, the treatment results in an increase in tendon strength of at least about 30%, at least about 40%, at least about 50%, at least about 60%, at least about 70% within about 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, or 21 days of administration of a composition of the invention, as compared to baseline. In some embodiments, the treatment results in an increase in tendon strength of at least about 30%, at least about 40%, at least about 50%, at least about 60%, at least about 70% within about 7 days of administration of a composition of the invention, as compared to baseline. In some embodiments, the treatment results in an increase in tendon strength of at least about 60% within about 7 days of administration of a composition of the invention, as compared to baseline. In some embodiments, the treatment results in an increase in tendon strength of at least about 65% within about 7 days of administration of a composition of the invention, as compared to baseline. In some embodiments, the treatment results in an increase in tendon strength of at least about 70% within about 7 days of administration of a composition of the invention, as compared to baseline. In some embodiments, the tendon achieves at least about 60%, at least about 70%, at least about 80%, at least about 90%, at least about 95% of its final strength within about 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, or 14 days of administration of a composition of the invention, wherein final strength is measured at about 21 days after treatment. In some embodiments, the tendon achieves at least about 80% of its final strength within about 7 days of administration of a composition of the invention, wherein final strength is measured at about 21 days after treatment. In some embodiments, the tendon achieves at least about 85% of its final strength within about 7 days of administration of a composition of the invention, wherein final strength is measured at about 21 days after treatment. In some embodiments, the tendon achieves at least about 90% of its final strength within about 7 days of administration of a composition of the invention, wherein final strength is measured at about 21 days after treatment. Tendon strength can be measured, for example, in an animal model, for

example in a rat collagenase model, wherein the tendon strength is the measured load to rupture. An example of measurement of tendon strength is described in more detail in Example 3.

Kits

In another aspect, provided herein are kits comprising a container containing a composition comprising PDGF and a buffer. In some embodiments, the kits comprise a first container containing a lyophilized PDGF and a second container containing a buffer for solubilizing the lyophilized PDGF. In some embodiments, the kits comprise a first container containing a lyophilized PDGF and buffer, and a second container containing water for solubilizing the lyophilized PDGF and buffer. In some embodiments, the buffer is selected from the group consisting of phosphate-buffered saline ("PBS"), sodium acetate, ammonium acetate, acetic acid, citric acid, sodium citrate, tris(hydroxymethyl) aminoethane ("tris"), N-2-hydroxyethylpiperazine-N'-2-ethanesulfonic acid ("HEPES"), 3-(N-morpholino) propanesulfonic acid ("MOPS"), 2-(N-morpholino)ethanesulfonic acid ("MES"), N-(2-acetamido)iminodiacetic acid ("ADA"), piperazine-N,N'-bis(2-ethanesulfonic acid) ("PIPES"), and N-(2-acetamido)-2-aminoethanesulfonic acid ("ACES"). In some embodiments, the buffer is sodium acetate. In some embodiments, the sodium acetate is at a concentration between about 10 mM and about 100 mM. In some embodiments, the sodium acetate is at a concentration of about 20 mM. In some embodiments, the sodium acetate is at a pH between about 4.0 and about 7.0. In some embodiments, the sodium acetate is at about pH 6.

In some embodiments, the kits further include other materials desirable from a commercial, therapeutic, and user standpoint, including other buffers, diluents, filters, needles, syringes, and package inserts with instructions for use. As used herein, the term "package insert" refers to instructions customarily included in commercial packages of medicaments that contain information about the indications customarily included in commercial packages of medicaments that contain information about the indications, usage, dosage, administration, contraindications, other medicaments to be combined with the packaged product, and/or warnings concerning the use of such medicaments.

Sutures

Also provided are PDGF coated sutures, and methods of making such sutures. The sutures may be used, for example, in treating a tendon in an individual (e.g. treating a tendon tear). Suitable sutures include, for example, those made from co-polymers of lactide and glycolide (such as Vicryl sutures (e.g. 4-0 Vicryl sutures)). Suitable coating methods include, for example, dip coating methods, such as the dip coating method described in Dines J, Weber L, Razzano P, et al. The Effect of Growth Differentiation Factor-5-Coated Sutures on Tendon Repair in a Rat Model. J Shoulder Elbow Surg 2007; 16:215 S-221S), which may optionally be altered to eliminate the gelatin. The applicants have surprisingly found that high doses of PDGF may be coated onto certain types of sutures in absence of gelatin. In some embodiments, the suture does not comprise gelatin. In some embodiments, the suture coating does not comprise gelatin. In some embodiments, the suture coating does not comprise polylactic, polyglycolic, or poly(lactic-co-glycolic) acid. In some embodiments, the method of coating the suture does not comprise utilizing gelatin. In some embodiments, the suture coating consists essentially of PDGF. In some embodiments, the suture coating consists of PDGF and a buffer. In some embodiments, the suture coating consists of PDGF. The sutures may be used to treat an individual, for example, a mammal. Non-limiting examples of mammals which may be treated using a suture of the invention include humans, pets (e.g. dogs, cats, rabbits, hamsters, etc.), laboratory animals (e.g. mice, rats), farm animals (e.g. horses, cows, sheep, goats, etc.).

In some embodiments, the amount of PDGF loaded onto the suture is at least about 10 ng PDGF/cm suture. In some embodiments, the amount of PDGF loaded onto the suture is at least about 100 ng PDGF/cm suture. In some embodiments, the amount of PDGF loaded onto the suture is at least about 1000 ng PDGF/cm suture. In some embodiments, the amount of PDGF loaded onto the suture is at least about 5000 ng PDGF/cm suture. In some embodiments, the amount of PDGF loaded onto the suture is at least about 6000 ng PDGF/cm suture. In some embodiments, the amount of PDGF loaded onto the suture is about 10 to about 20,000 ng PDGF/cm suture. In some embodiments, the amount of PDGF loaded onto the suture is about 100 to about 10,000 ng PDGF/cm suture. In some embodiments, the amount of PDGF loaded onto the suture is about 500 to about 8,000 ng PDGF/cm suture. In some embodiments, the amount of PDGF loaded onto the suture is about 1000 to about 8,000 ng PDGF/cm suture. In some embodiments, the amount of PDGF loaded onto the suture is about 4000 to about 8,000 ng PDGF/cm suture. In some embodiments, the amount of PDGF loaded onto the suture is about 6000 to about 7,000 ng PDGF/cm suture.

In some embodiments, the cumulative amount of PDGF released from the suture over 48-hours as measured in vitro is at least about 10 ng PDGF/cm suture. In some embodiments, the cumulative amount of PDGF released from the suture over 48-hours as measured in vitro is at least about 100 ng PDGF/cm suture. In some embodiments, the cumulative amount of PDGF released from the suture over 48-hours as measured in vitro is at least about 1000 ng PDGF/cm suture. In some embodiments, the cumulative amount of PDGF released from the suture over 48-hours as measured in vitro is at least about 5000 ng PDGF/cm suture. In some embodiments, the cumulative amount of PDGF released from the suture over 48-hours as measured in vitro is at least about 6000 ng PDGF/cm suture. In some embodiments, the cumulative amount of PDGF released from the suture over 48-hours as measured in vitro is about 10 to about 20,000 ng PDGF/cm suture. In some embodiments, the cumulative amount of PDGF released from the suture over 48-hours as measured in vitro is about 100 to about 10,000 ng PDGF/cm suture. In some embodiments, the cumulative amount of PDGF released from the suture over 48-hours as measured in vitro is about 500 to about 8,000 ng PDGF/cm suture. In some embodiments, the cumulative amount of PDGF released from the suture over 48-hours as measured in vitro is about 1000 to about 8,000 ng PDGF/cm suture. In some embodiments, the cumulative amount of PDGF released from the suture over 48-hours as measured in vitro is about 4000 to about 8,000 ng PDGF/cm suture. In some embodiments, the cumulative amount of PDGF released from the suture over 48-hours as measured in vitro is about 6000 to about 7,000 ng PDGF/cm suture. Suitable methods of measuring cumulative PDGF release in vitro include, for example, the method described in Example 7. The coated sutures of the invention may advantageously provide for consistent dosing in vivo.

The following examples are provided for illustrative purposes only and are not intended to limit the scope of the invention in any manner.

EXAMPLES

Example 1: Normal and Diseased Primary Human Tenocytes Proliferate in Response to rhPDGF-BB

This study determined whether rhPDGF-BB directly activated proliferation and/or chemotaxis of primary tenocytes derived from patients with tendinopathies. Such findings can support the notion of therapeutic potential of rhPDGF-BB in tendinopathies.

Patients and Methods

Patients

Ten patients with tendinopathies were involved in this study, including five patients with Achilles tendinopathy and five patients with tendinopathy of the posterior tibial tendon (PTT). An additional five patients were involved who underwent full joint replacement of the knee.

Primary Cultures of Tenocytes

Tendon tissue which would otherwise be discarded was obtained from normal and injured tendons during reconstructive surgery procedures performed for clinical indications. These tissues included the tendinopathic portion of the Achilles or PTT tendons, as well as the healthy (non-tendinopathic) portion of the flexor digitorum longus (FDL) tendon tissue, Achilles tendon tissue, and Patellar tendon tissue. Primary tenocyte explant cultures were obtained from these tissues and tested at passages 3 to 5. Tenocyte identity was confirmed by assessing the expression of a tenocyte-specific gene scleraxis and genes for collagens $\alpha 1(I)$, $\alpha 2(I)$, and $\alpha 1(III)$ in real-time PCR assays with specific primers.

Cell Proliferation

Tenocyte monolayers were trypsinized, resuspended in DMEM/F12 medium containing 0.5% dialyzed fetal bovine serum, allowed to attach overnight, and then incubated with titrated concentrations of rhPDGF-BB for 24 hours. Changes in cell proliferation rates were assessed based on BrdU incorporation during DNA synthesis in cells using a commercially available assay (Roche Applied Science, Indianapolis, Ind.). Each culture was tested in triplicates for each dose of rhPDGF-BB.

Cell Migration

Tenocyte monolayers were trypsinized, resuspended in DMEM/F12 medium containing 0.5% dialyzed fetal bovine serum and placed in the upper chamber of the 96-well ChemoTx® disposable cell migration system (Neuro Probe, Gaithersburg, Md.). The lower chambers contained titrated concentrations of rhPDGF-BB. Tenocytes were allowed to migrate across the membrane separating the chambers for 48 hours. 96-well plates were then spun down and freeze thawed three times to lyse the migrated cells. The amount of viable migrated cells was measured based on cytoplasmic lactate dehydrogenase (LDH) using a commercially available kit from Promega (Madison, Wis.).

Statistical Analysis

One-way ANOVA was used to determine whether stimulation with rhPDGF-BB affects tenocyte proliferation in a dose-dependent fashion.

Results

Only tenocyte cultures but not control pulmonary fibroblast cultures or control primary T lymphocyte cultures expressed scleraxis mRNA, whereas tenocytes and fibroblasts but not lymphocytes expressed the collagen gene mRNAs.

In all cases, tenocytes from tendon tissues involved or not involved in the disease process responded to rhPDGF-BB stimulation by accelerating BrdU incorporation ($p<0.05$, one-way ANOVA). The responses were dose-dependent and were observed at 10, 50 and 150 ng/mL of rhPDGF-BB. Even though all cell cultures responded to rhPDGF-BB stimulation, there was significant variability among patients in the magnitude of BrdU incorporation after rhPDGF-BB stimulation. Incorporation of BrdU increased from a minimum of 2.1±0.2 fold to a maximum of 10.7±0.5 fold compared to control non-stimulated cultures. Tenocytes from five patients responded paradoxically, with a greater increase in BrdU incorporation at a lower (10 ng/mL) rather than higher (50 and 150 ng/mL) concentrations of rhPDGF-BB. Such paradoxic response was observed in tenocytes derived from both tendinopathic and normal tissues of these patients. Tenocytes derived from healthy tendons of four patients incorporated twice more BrdU in response to rhPDGF-BB stimulation than did tenocytes derived from the diseased tissues. In one patient, tenocytes from the diseased tissue incorporated four fold more BrdU in response to rhPDGF stimulation than did tenocytes from the tissue uninvolved in the disease process. FIG. **2** shows the BrdU incorporation (y-axis, absorbance) for 0, 10, 50, and 150 ng/ml of PDGF added to the culture medium at day 1, day 4, and day 8 for healthy and diseased tenocytes. An increase in absorbance corresponds with increased proliferation, with both the healthy and diseased tenocytes responding to PDGF on day 1.

In all cases, tenocytes were chemotactically responsive to rhPDGF-BB at 50 ng/mL and 150 ng/mL. Tenocytes were not exposed to 10 ng/mL rhPDGF-BB for chemotaxis experiments because of low response in pilot experiments. Again, responses were dose-dependent, with greater chemotaxis to 150 ng/mL than to 50 ng/mL of rhPDGF-BB. However, tenocytes from 5 patients responded with greater chemotaxis to 50 ng/mL than to 150 ng/mL of rhPDGF-BB, with significant decline in the number of migrated cell ($p<0.05$, two-sided Student's t-test). There was variability among patients in the maximal chemotactic response to rhPDGF-BB, from 1.4±0.1 to 4.0±0.5 fold increase compared to non-stimulated control. There was no statistically significant difference ($p>0.05$) in tenocyte chemotaxis to rhPDGF-BB within matching tenocyte cultures derived from tendinopathic or from healthy tendon tissues. FIG. **1** shows the chemotaxis of cells (y-axis shows increased optical density) cultured in concentrations of 0, 50, or 150 ng/ml of PDGF. Migration was assessed with 1250, 2500, 5000, and 10000 initial cells.

Conclusion

The results of these experiments suggest that tenocytes derived from healthy and tendinopathic tissues respond to rhPDGF-BB by increasing proliferation and chemotaxis rates. Importantly, tenocytes from some patients showed paradoxical response to PDGF, in which higher doses caused less effect than lower doses. Equally important, tenocytes from diseased tendons were in some cases differentially responsive to PDGF versus tenocytes from healthy tendons, implying that proper dosing may be of paramount importance in the clinical setting.

Example 2: Safety Studies with rhPDGF-BB

Local Injection Test

The purpose of this study was to determine the local toxicity of rhPDGF-BB following an intra-Achilles tendon delivery to rats. The intra-Achilles tendon administration mimics the route of administration of rhPDGF-BB in the clinic for the treatment of lateral epicondylitis. The injection

site at the Achilles tendon-calcaneous junction mimics the insertion site of the extensor carpi radialis brevis tendon and lateral epicondyle bone.

The study used Sprague Dawley rats. The animals were housed at the same lab facility for the duration of the study. All housing and husbandry were in accordance with the Animal Welfare Act and the "Guide for the Care and Use of Laboratory Animals". Rats were fed and watered in accordance with standard protocols. Food and water were withheld for appropriate study related events such as anesthesia. Animals were acclimated to the facility for a minimum of 5 days prior to the study. This acclimation period allows the animals to become accustomed to the study room setting.

Three batches of sterile recombinant human PDGF-BB at different concentrations were used in the study: (1) 10.3 mg/ml rhPDGF-BB in 20 mM sodium acetate buffer, pH 6.0±0.5; (2) 5.2 mg/ml rhPDGF-BB in 20 mM sodium acetate buffer, pH 6.0±0.5; and (3) 1.7 mg/ml rhPDGF-BB in 20 mM sodium acetate buffer, pH 6.0±0.5. The vehicle control sample was sterile 20 mM sodium acetate buffer, pH 6.0±0.5, and was prepared according to standard procedures.

Standard laboratory safety procedures were employed for handling the test and control articles. Specifically, gloves, facemask, gown (or lab coat) and eye protection were worn while preparing and administering doses.

Animals were randomized into four groups, with n=60 per group, with each group having 30 males and 30 females. The groups each received a single intra-tendon injection at the osteotendinous junction of the quadriceps muscle of the following compounds: (1) 20 mM sodium acetate; (2) 51 μg rhPDGF-BB in 20 mM sodium acetate; (3) 156 μg rhPDGF-BB in 20 mM sodium acetate; or (4) 515 μg rhPDGF-BB in 20 mM sodium acetate. Injections were performed with insulin syringes equipped with a 28.5 G needle. All animals received test article on Day 1 via a single intra-Achilles tendon injection. Group 1 animals received sodium acetate (NaOAc), while Group 2-4 animals received rhPDGF-BB at dose levels of 36.69, 112.23, and 370.50 μg/mm2, respectively.

One third of each group was sacrificed at 1 day, 2 weeks, and 6 weeks post-rhPDGF-BB injection. Upon completion of the in-life treatment groups, animals were euthanized and tissues harvested in accordance with the USDA Animal Welfare Act, The Guide for Care and Use of Laboratory Animals (ILAR publication, 1996, National Academy Press), and HSS veterinary procedures. Animals were euthanized by CO_2 overdose. Death was confirmed by lack of reflexes (blinking, withdrawal, etc.).

Criteria for evaluation included clinical observations, physical evaluations, body weight and food consumption measurements, clinical pathology, necropsy, organ weights, and histopathology evaluation of the injected and noninjected hind leg ankles, including an examination of tendon toxicity and bone toxicity.

Animals underwent a hematological assessment, a coagulation study, and a variety of clinical chemistry studies. The hematological assessment included the following measures: a leukocyte count (WBC); an erythrocyte Count (RBC); determination of hemoglobin (Hb), mean corpuscular hemoglobin (MCH) levels, hematocrit (HCT), and mean corpuscular Hb concentration (MCHC); a platelet count; determination of mean corpuscular volume (MCV), and an assessment of leukocyte differential, including neutrophil, lymphcyte, monocyte, eosinophil, basophil, % neutrophil, % lymphocyte, % monocyte, and % eosinophil). The coagulation study measured activated partial thromboplastin time (APTT) and prothrombin time (PT). Clinical chemistry studies included analysis of the following: alkaline phosphatase (ALP), glucose (GLU), albumin (ALB), alanine aminotransferase (ALT), total bilirubin (TBIL), globulin (Glob), aspartate aminotransferase (AST), cholesterol (CHOL), potassium (K), gamma glutamyltransferase (GGT), triglycerides (TRIG), chloride (Cl), creatinine (CREAT), blood urea nitrogen (BUN), sodium (Na), inorganic phosphorus (PHOS), calcium (Ca), A/G ratio, and total protein (TPROT).

Results

Single intra-Achilles tendon injection of rhPDGF-BB to rats at dose levels 36.69 μg/mm2, 112.23 μg/mm2, 370.50 μg/mm2 had no effect on mortality or moribundity. Furthermore, there were no test article-associated biologically significant differences in clinical observations, effects on body weight, or food consumption.

On Day 2, there were no statistically or biologically significant differences in any of the hematology or urinalysis parameters analyzed for the any of the groups of treated rats when compared to the controls (Group 1). Changes were observed in leukocyte and coagulation parameters, but these changes were consistent with a minimal acute inflammatory response to the injection of a foreign protein. In addition, minimal changes were also observed in several serum chemistry parameters. However, these changes were considered to be the result of individual animal variation, were not considered to be biologically significant, and were not associated with any organ specific toxicity.

On Days 16 and 43, there were no biologically significant differences in any of the hematology, leukocyte, coagulation, or urinalysis parameters analyzed for the any of the groups of treated rats when compared to the controls (Group 1).

There were no test article-associated macroscopic observations; all macroscopic observations were considered to be incidental.

Acute hemorrhage and subacute inflammation was observed on Day 2 in the controls and the treated groups of rats, although the frequency and severity appeared to greater in the treated groups of rats. On Day 16, acute hemorrhage has subsided and subacute inflammation was infrequent. Treated groups of rats demonstrated fibroplasia and neovascularization of the paratendons of the superficial flexor tendon and calcaneal tendon in addition to hypertrophy and hyperplasia of tenocytes of the aforementioned tendons. By Day 43, the severity of the fibroplasia and neovascularization had ameliorated; tenocytes still demonstrated hypertrophy and hyperplasia in the majority of treated rats.

Second Species Local Injection Test.

The objective of this study is to determine the local toxicity of recombinant human platelet-derived growth factor (rhPDGF-BB) following intra-Achilles tendon delivery to dogs.

The study uses Beagle dogs. The animals are housed at the same lab facility for the duration of the study. All housing and husbandry is in accordance with the Animal Welfare Act and the "Guide for the Care and Use of Laboratory Animals". Dogs are fed and watered in accordance with standard protocols. Food and water are withheld for appropriate study related events such as anesthesia. Animals are acclimated to the facility for a minimum of 5 days prior to the study. This acclimation period allows the animals to become accustomed to the study room setting.

Three batches of sterile recombinant human PDGF-BB at different concentrations are used in the study: (1) 10 mg/ml rhPDGF-BB in 20 mM sodium acetate buffer, pH 6.0±0.5; (2)3 mg/ml rhPDGF-BB in 20 mM sodium acetate buffer,

pH 6.0±0.5; and (3) 1 mg/ml rhPDGF-BB in 20 mM sodium acetate buffer, pH 6.0±0.5. The vehicle control sample is sterile 20 mM sodium acetate buffer, pH 6.0±0.5, and is prepared according to standard procedures.

Standard laboratory safety procedures are employed for handling the test and control articles. Specifically, gloves, facemask, gown (or lab coat) and eye protection are worn while preparing and administering doses.

Animals are randomized into four groups, with n=24 per group, with each group having 12 males and 12 females. The groups each receive a single intra-tendon injection at the osteotendinous junction of the quadriceps muscle of the following compositions: (1) 20 mM sodium acetate; (2) 1.5 mg rhPDGF-BB in 20 mM sodium acetate; (3) 4.5 mg rhPDGF-BB in 20 mM sodium acetate; or (4) 15 mg rhPDGF-BB in 20 mM sodium acetate. Injections are performed with insulin syringes equipped with a 28.5 G needle with a fixed dose volume of 1.5 ml.

One third of each group is sacrificed at 1 day, 2 weeks, and 6 weeks post-rhPDGF-BB injection. Upon completion of the in-life treatment groups, animals are euthanized and tissues harvested in accordance with the USDA Animal Welfare Act, The Guide for Care and Use of Laboratory Animals (ILAR publication, 1996, National Academy Press), and HSS veterinary procedures. Animals are euthanized by exsanguination while under deep anesthesia induced with sodium pentobarbital (Fatal-Plus® or an appropriate alternative).

Animals undergo a hematological assessment, a coagulation study, and a variety of clinical chemistry studies.

The hematological assessment includes the following measures: a leukocyte count (WBC); an erythrocyte Count (RBC); determination of hemoglobin (Hb), mean corpuscular hemoglobin (MCH) levels, hematocrit (HCT), and mean corpuscular Hb concentration (MCHC); a platelet count; determination of mean corpuscular volume (MCV), and an assessment of leukocyte differential, including neutrophil, lymphcyte, monocyte, eosinophil, basophil, % neutrophil, % lymphocyte, % monocyte, and % eosinophil). The coagulation study measures activated partial thromboplastin time (APTT) and prothrombin time (PT). Clinical chemistry studies includes analysis of the following: alkaline phosphatase (ALP), glucose (GLU), albumin (ALB), alanine aminotransferase (ALT), total bilirubin (TBIL), globulin (Glob), aspartate aminotransferase (AST), cholesterol (CHOL), potassium (K), gamma glutamyltransferase (GGT), triglycerides (TRIG), chloride (Cl), creatinine (CREAT), blood urea nitrogen (BUN), sodium (Na), inorganic phosphorus (PHOS), calcium (Ca), A/G ratio, and total protein (TPROT).

Local tissue histopathology is also evaluated, including an examination of tendon toxicity and bone toxicity.

The rhPDGF-BB is not toxic to the dogs.

Acute Systemic Toxicity.

The objective of this study is to determine the systemic toxicity of rhPDGF-BB administered by intravenous injection.

The study uses Sprague-Dawley rats. The animals are housed at the same lab facility for the duration of the study. All housing and husbandry is in accordance with the Animal Welfare Act and the "Guide for the Care and Use of Laboratory Animals". Animals are fed and watered in accordance with standard protocols. Food and water are withheld for appropriate study related events such as anesthesia. Animals are acclimated to the facility for a minimum of 5 days prior to the study. This acclimation period allows the animals to become accustomed to the study room setting.

Sterile recombinant human PDGF-BB at 3.0 mg/ml and 0.3 mg/ml in 20 mM sodium acetate buffer, pH 6.0±0.5 is used in the study. On the day of dosing, a portion of the 0.3 mg/mL solution is diluted 1:10 in 20 mM sodium acetate buffer to create a 0.03 mg/ml solution which also is used in the study. The control sample is sterile 20 mM sodium acetate buffer, pH 6.0±0.5, and is prepared according to standard procedures.

Standard laboratory safety procedures are employed for handling the test and control articles. Specifically, gloves, facemask, gown (or lab coat) and eye protection are worn while preparing and administering doses.

Animals are randomized into four groups, with n=40 per group (20 males and 20 females/group). Dose group 1 receives a single intravenous injection of 20 mM sodium acetate, pH 6.0±0.5 at a volume of 1.4 ml/kg; dose group 2 receives a single intravenous injection of 3.0 mg/ml rhPDGF-BB in 20 mM sodium acetate, pH 6.0±0.5 at a volume of 1.4 ml/kg; dose group 3 receives a single intravenous injection of 0.3 mg/ml rhPDGF-BB in 20 mM sodium acetate, pH 6.0±0.5 at a volume of 1.4 ml/kg; dose group 4 receives a single intravenous injection of 0.03 mg/ml rhPDGF-BB in 20 mM sodium acetate, pH 6.0±0.5 at a volume of 1.4 ml/kg.

Animals are evaluated for death and other signs of severe toxicity. During the study duration, animals are observed for viability, clinical examinations, body weights, food consumption, ophthalmic examination, and clinical pathology. Upon necropsy on day 2 and day 14 (10 males and 10 females/group/timepoint), animals undergo a clinical pathology evaluation, including hematology, coagulation, serum chemistry, and urinalysis, as well as a full necropsy.

Example 3: Dose Response of Intra-Tendon (IT) Application of rhPDGF-BB in the Collagenase-Induced Rat Achilles Tendon Injury Model

The objective of the study was to determine the dose-response of an intra-tendon application of rhPDGF-BB in a rat tendon collagenase model to validate the reparative effect of rhPDGF-BB on Achilles tendon injury and remodeling. We hypothesized that intra-tendon delivery of rhPDGF-BB will result in tendon repair by upregulating cell proliferation and restoring biomechanical strength of the tendon.

The recombinant human platelet-derived growth factor BB (rhPDGF-BB) is mitogenic and chemotactic for cells of mesenchymal origin, such as osteoblasts, tenocytes, chondrocytes and mesenchymal stem cells. Thus, when introduced into musculoskeletal sites of injury, rhPDGF-BB attracts connective tissue cells and progenitors to the treatment site, stimulating their proliferation, resulting in increased numbers of cells which subsequently deposit matrix to regenerate the injured tissue(s). In addition, as shown in Example 1 above, tenocytes exposed to PDGF-BB showed an increase in DNA synthesis and chemotaxis.

Collagenase-Induced Rat Achilles Tendon Injury Model

There is not a single well-established model for the evaluation of tendinopathy. However, the collagenase-induced rat Achilles tendon injury model has been widely used for Achilles tendon injury. This model initiates a degenerative tendon response regarded as being equivalent to tendinitis, and develops tendinitis injury quickly (within 3 days) compared to the uphill treadmill overuse model (4 months). Thus, it is a quick model to screen for the effect of rhPDGF-BB on tendon injury. Therefore, the model enjoys a relatively rapid induction period and is highly suitable and

representative of clinical tendinitis as a screen for the therapeutic effect of rhPDGF-BB.

A total of one hundred sixty five (165) male Sprague Dawley rats were used in this study. They were administered a collagenase injection in their right Achilles tendon followed by a single injection treatment of rhPDGF-BB or control (buffer only) at the site of injury 7 days after the collagenase injection. Collagenase and rhPDGF-BB or control (buffer only) was injected into right Achilles tendons of rats near the osseous-tendon junction using insulin syringes with 28.5 G needles.

The animals were divided into 11 groups with n=15 in each group, as outlined in Table 1. Studies reported in the literature utilizing this model have historically used 8-9 animals per treatment group for biomechanical testing and 3-6 animals for histological analysis.

Test and Control Articles

The study control group utilized the natural reparative response of rat tendon in the collagenase-treated rat Achilles tendon without rhPDGF-BB as a control to approximate the natural healing response of an injured tendon. The study test article used rhPDGF-BB as an injectable drug to aid in the regeneration of tendon. The recombinant human platelet-derived growth factor BB (rhPDGF-BB) is mitogenic and chemotactic for cells of mesenchymal origin, such as osteoblasts, tenocytes, chondrocytes and mesenchymal stem cells. Thus, when introduced into musculoskeletal sites of injury, rhPDGF-BB attracts connective tissue cells and progenitors to the treatment site, stimulating their proliferation, resulting in increased numbers of cells which subsequently deposit matrix to regenerate the injured tissue(s). In addition, as shown in Example 1 above, tenocytes exposed to PDGF-BB showed an increase in DNA synthesis and chemotaxis.

Two batches of sterile recombinant human PDGF-BB at different concentrations were used in the study: (1) 3.4 mg/ml rhPDGF-BB in 20 mM sodium acetate buffer, pH 6.0±0.5; and (2) 0.34 mg/ml rhPDGF-BB in 20 mM sodium acetate buffer, pH 6.0±0.5. The vehicle control sample was sterile 20 mM sodium acetate buffer, pH 6.0±0.5, prepared according to standard procedures. Doses include: 1.02 μg, 10.2 μg and 102 μg rhPDGF-BB. Two concentrations of rhPDGF-BB in NaOAc buffer were prepared: 3.4 mg/ml and 0.34 mg/ml. When delivered at 30 μl intratendon, 102 μg and 10.2 μg dose levels were achieved. For the 1.02 μg dose, the 0.34 mg/mL solution was diluted 1:10 with 20 mM NaOAc buffer. Collagenase was purchased in powder form from Sigma-Aldrich (Catalog No. C-6885; St. Louis, Mo.) and reconstituted to the desired concentration (10 mg/mL) in PBS containing 50 mM NaH_2PO_4 and 150 mM NaCl at pH 7.4±0.5.

At study initiation, at least two unopened, unused vials of the 3.4 mg/ml rhPDGF-BB, 0.34 mg/ml rhPDGF-BB, and 20 mM sodium acetate buffer test articles were retained under the same storage conditions (4° C.) as the vials used for dosing, stability and concentration analysis. Stability and dose verification analyses were performed using UV/Vis spectrophotometry and reverse phase HPLC analyses.

Standard laboratory safety procedures were employed for handling the test and vehicle control articles. Specifically, gloves, facemask, gown (or lab coat) and eye protection were worn while preparing and administering doses.

Test System (Animals and Animal Care)

One hundred sixty five (165) male Sprague Dawley rats (Charles River Laboratories, Intl, Wilmington, Mass.) were used in this study. Prior to study selection, all animals were screened by visual examination to ensure health and normal gait. All animals were selected for the study based upon their weight (approximately 315 grams at the time of collagenase injection). Each rat was identified by a unique number written on their tails. Rats were assigned randomly to each group according to their body weights.

The rats were housed at the same lab facility for the duration of the study. All housing and husbandry was in accordance with the Animal Welfare Act and the "Guide for the Care and Use of Laboratory Animals". Food and water was withheld for appropriate study related events such as anesthesia but was otherwise provided ad libitum. Animals were acclimated to the facility for a minimum of 5 days prior to the study. This acclimation period allowed the animals to become accustomed to the study room setting.

Experimental Design

Animals (15 per group), housed 4 per cage, were anesthetized with isoflurane and the hock area clipped and cleaned for injection. Collagenase (50 μl of 10 mg/ml dissolved in PBS containing 50 mM NaH_2PO_4 and 150 mM NaCl at pH 7.4) was injected into the right Achilles tendons of all rats near the osseous-tendon junction using insulin syringes with 28.5 G needles (FIG. **3**). Seven days post collagenase injection, treatments with vehicle or 1.02 μg, 10.2 μg or 102 μg of rhPDGF-BB in 30 μl total volume were administered using insulin syringes with 28.5 G needles. Animals were terminated at 7 (baseline) 14, and 28 days for histopathologic evaluation of tendon damage and biomechanics. In each group of 15 animals, 6 animals were used for histopathology and the hind legs of 9 animals (both treated and non-treated rear limbs) was removed, dissected, and frozen for subsequent biomechanical evaluation. Description of the biomechanical evaluation is provided below.

TABLE 1

Treatment Groups				
Group number	Treatment Group	Animals (n)	rhPDGF-BB	Endpoint
1	Collagenase + No treatment Terminate Day 7 (Baseline)	15	0	Biomechanics (N = 9)/ Histology (N = 6)
2	Collagenase + No treatment Terminate Day 14	15	0	Biomechanics (N = 9)/ Histology (N = 6)
3	Collagenase + No treatment Terminate Day 28	15	0	Biomechanics (N = 9)/ Histology (N = 6)
4	Collagenase + Sodium Acetate Terminate Day 14	15	0	Biomechanics (N = 9)/ Histology (N = 6)
5	Collagenase + Sodium Acetate Terminate Day 28	15	0	Biomechanics (N = 9)/ Histology (N = 6)
6	Collagenase + rhPDGF-BB Terminate Day 14	15	102 μg	Biomechanics (N = 9)/ Histology (N = 6)
7	Collagenase + rhPDGF-BB Terminate Day 28	15	102 μg	Biomechanics (N = 9)/ Histology (N = 6)
8	Collagenase + rhPDGF-BB Terminate Day 14	15	10.2 μg	Biomechanics (N = 9)/ Histology (N = 6)
9	Collagenase + rhPDGF-BB Terminate Day 28	15	10.2 μg	Biomechanics (N = 9)/ Histology (N = 6)
10	Collagenase + rhPDGF-BB Terminate Day 14	15	1.02 μg	Biomechanics (N = 9)/ Histology (N = 6)

TABLE 1-continued

Treatment Groups				
Group number	Treatment Group	Animals (n)	rhPDGF-BB	Endpoint
11	Collagenase + rhPDGF-BB Terminate Day 28	15	1.02 μg	Biomechanics (N = 9)/ Histology (N = 6)

In-Life Observations and Measurements

Animals were observed at least daily until sacrifice. Treatment of the animals was in accordance with the regulations outlined in the USDA Animal Welfare Act (9 CFR, Parts 1, 2, and 3) and the conditions specified in The Guide for Care and Use of Laboratory Animals (ILAR publication, 1996, National Academy Press), and HSS veterinary procedures.

Body weights were recorded prior to the collagenase injection and before sacrifice. Food consumption was qualitative.

All animals were sacrificed at the appropriate study end points. No unscheduled animal deaths were observed. Upon the completion of the in-life treatment groups, animals were euthanized and tissues harvested in accordance with the USDA Animal Welfare Act, The Guide for Care and Use of Laboratory Animals (ILAR publication, 1996, National Academy Press), and HSS veterinary procedures. Animals were euthanized by CO_2 overdose. Death was confirmed by lack of reflexes (blinking, withdrawal, etc.).

Gross Tendon Size

Immediately prior to necropsy, ankles were scored for thickness according to the following systems: 0=no growth; 1=mild growth; 2=moderate growth; 3=severe growth.

Histology

At necropsy, the skin was carefully removed from the hock area with the entire foot submerged in 10% neutral buffered formalin (NBF) and fixed in flexion. After a minimum of 12 hours in 10% NBF and 4-5 days in 10% formic acid to decalcify, the ankle, with special emphasis on the tendon-osseous junction was trimmed both medially and laterally to achieve an approximately ¼ inch thick tissue block (central portion of ankle with tendon attachment) and placed in labeled tissue cassettes. The trimmed ankle tissue block was processed for paraffin embedding in the saggital orientation. Using a rotary microtome, representative 4-6 micron thick sections were taken at 200 micron step sections until suitable visualization of the osseous-tendon junction was achieved and those sections were then stained with hematoxylin and eosin (H&E), Masson's Trichrome, and for immunohistochemistical (IHC) detection of proliferating cell nuclear antigen (PCNA).

All animals were bled for serum terminally by descending aorta vacutainer while under Isoflurane anesthesia (10 mls blood were collected). The blood was centrifuged at 1,800 g at room temperature for 10 minutes to obtain serum. Up to 1 ml of serum was provided in 2 ml Eppendorf® tubes. The serum was stored at −70° C. prior to analysis.

Histopathological assessment was performed as described below. Measurements for different parameters were made by assessing three equidistant field columns from each histologic specimen (slide) using light microscopy.

The measured parameters for histopathology included:

(1) Inflammation. Inflammatory cell types (neutrophils, lymphocytes, and macrophages) were determined by H&E staining. Inflammation was scored as follows: (a) 0=no inflammation; (b) 1=minimal inflammation (100% Mononuclear; no neutrophils); (c) 2=moderate inflammation (neutrophils ≤19%; remainder of cells mononuclear); and (d) 3=marked inflammation (neutrophils ≥20%; remainder of cells mononuclear).

(2) Collagen organization. Organization of collagen fibrils was assessed by H&E and Trichrome staining. Collagen organization was scored as follows: (a) 0=collagen fibrils are completely disorganized; (b) 1=some alignment of the collagen fibrils but the majority of the bundles are highly disorganized; (c) 2=the collagen fibrils are highly aligned however the bundles are still somewhat disorganized; and (d) 3=the collagen fibrils present in the tissue are completely aligned and there is no disorganization of the collagen bundles.

(3) Collagen fiber density. Collagen fiber density in the repair tissue was assessed by H&E and Trichrome staining. Collagen fiber density was scored as follows: (a) 0=low density collagen bundles; (b) 1=medium density collagen bundles; and (c) 2=highly dense collagen bundles.

(4) Tendon vascularization at site of repair. Vascularization in the repair tissue was determined by H&E and Trichrome staining. Vascularization was scored as follows: (a) 0=none (no vascularization present); (b) 1=moderate; and (c) 2=abundant.

(5) Cell proliferation. Cell proliferation was evaluated using immunohistochemistry (IHC) for PCNA (proliferating cell nuclear antigen). An ocular micrometer was used to delineate an area that was 39.4×197 μm (7762 μm2), or 10×50 units on the micrometer. Three fields having this measurement were counted for each specimen. Proliferating cells were counted from these 3 equidistant fields.

(6) Tendon Width Measurements. Measurements of the tendon at two different locations were taken under the microscope and using an ocular micrometer. Measurements were taken of the calcaneous attachment point (non-tangential area thought to best represent the thickness of the attachment site) and of the tendon itself (thickest non-tangential area of the tendon body remote from the attachment site with associated proliferative response).

Semi-quantitative histopathology data was analyzed using Mann-Whitney U test or Kruskal-Wallis test (non-parametric). Applicable data was analyzed across all groups, using a one-way analysis of variance (1-way ANOVA), along with the appropriate multiple comparison post-test.

Biomechanical Testing

99 animals were utilized for this portion of the study. The injury-induced tendon was evaluated in addition to contralateral non-collagenase treated tendons. A total of 123 biomechanical specimens were evaluated. Treatment allocations are outlined in Table 1 above.

The leg was detached at the femur and de-sleeved to the mid-foot. Using a scalpel, the Achilles-gastrocnemius complex was detached from the tibia. Briefly, starting at the calcaneal insertion the scalpel was run along the tibia to separate the complex and a majority of muscle was left attached to the tendon to allow for gripping for biomechanical testing. After separation of the tendon, tibia was removed at the junction with the metatarsus, leaving the foot attached for gripping at distal end for biomechanical testing (FIG. **4**). The entire metatarsus-Achilles-gastrocnemius specimen was wrapped in saline-soaked gauze and frozen at −20° C. for storage before performing biomechanical analysis.

Samples were thawed in PBS containing proteinase inhibitors at 4° C. up to 4 hours prior to mechanical testing. Tendon samples were patted dry, and excess muscle was removed to facilitate mounting of samples in grips. Bone was trimmed with clippers to facilitate mounting.

All mechanical testing was performed on an Instron testing frame (Model 5566) where samples were tested while submersed in a bath containing PBS. Precise displacement control was applied to each specimen, and the resulting load was measured using a 100N load cell with load accuracy of ±0.5%. All data acquisition and device control was performed with a personal computer, where data will be acquired at 10 Hz.

Specimens were mounted in hydraulic grips between two roughened surface plates and sand paper, in order to prevent slippage of the sample during pull testing. A pre-load of 0.1N was applied to the specimens, and the length of the specimen was recorded followed by precycling for 10 cycles between loads of 0.1 and 1N. A uniaxial tensile displacement was applied to the constructs at a strain rate of 0.1% per second, and the resultant load was recorded. The samples will be tested to failure in tension, until fracture is reached and the measured load is observed to be <0.05N. Prior to testing, the cross sectional area of the specimen was measured. All specimens were tested blinded with no indication of identifiable group classification.

After testing, the collected data was analyzed to determine: (1) linear stiffness and (2) elastic modulus from the linear portion of the load-displacement or stress-strain curve, respectively. The maximum load and ultimate tensile strength were also determined from the loading data. The elastic toughness, defined as the area under the force displacement curve until peak load, will be calculated numerically using the Reimann sum method.

Two-way ANOVA with interaction and a Fisher's LSD post-hoc test ($p<0.05$) was used for analysis of the biomechanical data. Applicable data was analyzed across all groups, using a one-way analysis of variance (1-way ANOVA), along with the appropriate multiple comparison post-test.

Stress is the load on the specimen normalized to the cross sectional area of the sample. Strain represents the change in length of the specimen normalized to the original length of the sample. Consequently, the stress vs. strain curve is a normalized version of the load vs. displacement curve (eliminates the effect of variation in the specimen dimensions). For example, a longer tendon will have greater total displacement. On the other hand, a wider tendon can withhold more load than a narrower one. These slight variations in the specimen to specimen dimensions significantly affect the magnitude of load and displacement they can bear. When these variables are normalized by their dimensions to stress and strain, the analysis is no longer dependent on the size of the specimen. All properties extracted directly from the load vs. displacement curves are referred to as structural properties. All properties extracted from the normalized stress vs. strain curves are referred to as material properties.

Linear Stiffness is a structural property that is determined from a least-square fit of the linear portion of the load vs. displacement curve. It represents the tensile stiffness of the specimen.

Elastic Modulus is a material property that is determined from a least-square fit of the linear portion of the stress vs. strain curve. It represents the tensile stiffness of the tendon material.

Maximum Load is the largest load that the specimen can withstand during pulling.

Ultimate Tensile stress is the maximum load normalized by the specimen's cross sectional area.

Toughness is resistance of a material to fracture or break. It is usually measured in units of energy, and calculated as the area under the load-displacement curve until failure.

Results

Effect of rhPDGF-BB on Gross Ankle Thickness

A dose-dependent increase in gross ankle thickness was observed seven days post single intra-tendon injection of rhPDGF-BB (FIG. **6**A and FIG. **7**, Day 7 Post Tx), with the medium (10.2 μg) and high (102 μg) dose producing a significant increase in tendon size at seven days post-injection. At Day 21 Post Tx, all groups except the vehicle control group (the sodium acetate buffer) exhibited a decrease in gross ankle thickness, suggesting tissue remodeling at day 21 post-treatment (FIG. **6**B and FIG. **7**, Day 21 Post Tx). The data in FIGS. **6**A, **6**B, and **7** were based on an analog scale at 7- and 21-days post-rhPDGF-BB treatment (0=no growth to 3=severe growth). Data reported are means of the ankle thickness (±SEM) of n=6 animals per group.

Effect of rhPDGF-BB on Body Weights

At the time of treatment, the average body weight of the animals was 314.48 grams. At 7- and 21-days post-treatment the average body weights were 396.4 and 467.0 grams, respectively. There were no treatment related changes in body weight at either time point.

Effect of rhPDGF-BB on Bone

Neither abnormal bone growth nor resorption was identified.

Effect of rhPDGF-BB on Tendon Width at the Calcaneous Attachment

FIG. **8** shows the measured tendon width (μm±SEM) at the Calcaneous insertion at day 7 and 21 post-treatment. Data reported are means of the tendon width (±SEM) at the calcaneous insertion of n=6 animals per group; * p=0.01 vs. vehicle control group. The tendon width was measured by microscopy using an ocular micrometer.

Seven days post-treatment (Day 7 Post Tx) a significant increase (~137% increase) in the tendon width at the calcaneous insertion with the 32.4 μg/kg rhPDGF-BB dose-group as compared to vehicle was observed (FIG. **8**, Day 7 Post Tx). Animals treated with 3.24 and 324 μg/kg rhPDGF-BB did not demonstrate a significant increase in tendon width, but trended higher as compared to vehicle control. No significant difference between the tendon widths of animals treated with or without rhPDGF-BB was determined at day 21 post-treatment (FIG. **8**, Day 21 Post Tx). By day 21 post-treatment (FIG. **8**, Day 21 Post Tx), the 32.4 μg/kg rhPDGF-BB dose group exhibited a 40% decrease in tendon width as compared to day 7 post-treatment, suggesting the tendon remodeled (FIG. **8**).

Effect of rhPDGF-BB on Tendon Width at the Tendon Mid-Body

FIG. **9** represents the measured tendon width (μm±SEM) at the tendon mid-body at day 7 and 21 post-treatment. Data reported are means of tendon width (±SEM) at the tendon body of n=6 animals per group; * p<0.05 vs. vehicle group. The tendon width was measured by microscopy using an ocular micrometer.

An ~97% increase in tendon width was observed with the 32.4 μg/kg rhPDGF-BB dose vs. vehicle control group at day 7 post-treatment (FIG. **9**, Day 7 Post Tx). A non-significant dose-dependent increase was observed in the 3.24 and 324 μg/kg dose groups vs. vehicle and no treatment (Tx) groups. By day 21, no significant differences in tendon widths were observed across groups (FIG. **9**, Day 21 Post Tx). However, at day 21, the 32.4 μg/kg rhPDGF-BB dose group exhibited a 116% decrease in tendon width as compared to day 7 post-treatment, suggesting the tendon remodeled.

Effect of rhPDGF-BB on Cell Proliferation

Quantitation of cell proliferation was done by cell counts of positive PCNA immunostained cells (FIG. **10**). Data reported are means of cell counts (±SEM) of n=6 animals per group; * $p<0.05$ vs. vehicle. Three fields having equal measurement were counted for each specimen.

A dose-dependent increase in cellular density was observed in the rhPDGF-BB groups. An rhPDGF-BB dose-dependent increase in cell proliferation was observed at day 7 post-treatment (FIG. **10**, Day 7 Post Tx); a significant increase in cellular proliferation was observed in the 32.4 and 324 μg/kg dose groups vs. vehicle control (FIG. **10**, Day 7 Post Tx), representing a ~60% and ~72% increase respectively. However, by day 21, no significant difference in cell proliferation was observed (FIG. **10**, Day 21 Post Tx). A return to vehicle control proliferation level was observed for the 32.4 and 324 μg/kg rhPDGF-BB dose groups, indicating that the proliferative response of rhPDGF-BB was reversible (FIG. **10**, Day 21 Post Tx).

Effect of rhPDGF-BB on Inflammation

Mild to moderate inflammation consisting of macrophages and mononuclear cells was observed across all groups at all time points (Table 2).

TABLE 2

Effect of rhPDGF-BB on inflammation using an analog scale (0 = no inflammation to 3 = severe inflammation) at 7- and 21-days following treatment.

		Groups				
Animal Number	Base-line	No Tx	Vehicle	3.24 μg/kg	32.4 μg/kg	324 μg/kg
7 Days Post-Tx						
1	2	1	1	1	2	2
2	2	1	2	2	2	1
3	2	1	1	2	2	2
4	2	1	1	2	2	1
5	2	1	1	2	2	2
6	2	2	2	2	2	2
Mean	2	1.167	1.333	1.833	2	1.667
SD	0	0.408	0.516	0.408	0	0.516
21 Days Post-Tx						
1	2	1	1	1	1	1
2	2	1	2	1	1	1
3	2	1	2	1	1	2
4	2	1	1	1	1	2
5	2	2	1	1	1	2
6	2	1	1	1	1	2
Mean	2	1.167	1.333	1	1	1.667
SD	0	0.408	0.516	0	0	0.516

Effect of rhPDGF-BB on Vascularization

No significant change in vascularization was observed across all groups and time points (Table 3).

TABLE 3

Effect of rhPDGF-BB on vascularization using an analog scale (0 = none to 2 = severe) at 7- and 21-days following treatment.

		Groups				
Animal Number	Base-line	No Tx	Vehicle	3.24 μg/kg	32.4 μg/kg	324 μg/kg
7 Days Post-Tx						
1	1	2	2	1	2	2
2	0	2	2	2	2	1

TABLE 3-continued

Effect of rhPDGF-BB on vascularization using an analog scale (0 = none to 2 = severe) at 7- and 21-days following treatment.

		Groups				
Animal Number	Base-line	No Tx	Vehicle	3.24 μg/kg	32.4 μg/kg	324 μg/kg
3	2	1	1	2	2	2
4	2	1	1	2	2	2
5	1	2	1	2	2	2
6	2	2	2	2	2	2
Mean	1.333	1.667	1.5	1.833	2	1.833
SD	0.816	0.516	0.548	0.408	0	0.408
21 Days Post-Tx						
1	1	1	1	0	1	2
2	0	1	2	1	1	1
3	2	1	2	1	2	2
4	2	1	1	2	1	2
5	1	2	1	2	1	1
6	2	1	1	1	2	1
Mean	1.333	1.167	1.333	1.167	1.333	1.5
SD	0.816	0.408	0.516	0.753	0.516	0.548

Effect of rhPDGF-BB on Collagen Density

No significant change in collagen density was observed across all groups and time points (Table 4).

TABLE 4

Effect of rhPDGF-BB on collagen density using an analog scale (0 = none to 2 = severe) at 7- and 21-days following treatment.

		Groups				
Animal Number	Base-line	No Tx	Vehicle	3.24 μg/kg	32.4 μg/kg	324 μg/kg
7 Days Post-Tx						
1	1	1	2	2	1	1
2	1	1	1	1	1	2
3	1	1	2	1	1	1
4	1	1	2	1	1	2
5	2	1	2	1	1	2
6	1	1	1	1	1	2
Mean	1.167	1	1.667	1.167	1	1.667
SD	0.408	0	0.516	0.408	0	0.516
21 Days Post-Tx						
1	1	2	2	2	2	2
2	1	2	1	2	2	2
3	1	2	1	2	2	1
4	1	2	2	2	2	1
5	2	2	2	2	2	2
6	1	2	2	2	2	2
Mean	1.167	2	1.667	2	2	1.667
SD	0.408	0	0.516	0	0	0.516

Effect of rhPDGF-BB on Collagen Organization

No significant change in collagen organization was observed across all groups and time points (Table 5).

TABLE 5

Effect of rhPDGF-BB on collagen organization using an analog scale (0 = none to 3 = highly organized) at 7- and 21-days following treatment.

		Groups				
Animal Number	Base-line	No Tx	Vehicle	3.24 μg/kg	32.4 μg/kg	324 μg/kg
7 Days Post-Tx						
1	1	2	3	3	2	2
2	1	2	2	2	2	3
3	1	2	3	2	2	2
4	2	2	3	2	2	3
5	3	2	3	2	2	2
6	1	2	2	2	2	3
Mean	1.5	2	2.667	2.167	2	2.5
SD	0.837	0	0.516	0.408	0	0.548
21 Days Post-Tx						
1	1	3	3	3	3	3
2	1	3	2	3	3	3
3	1	3	2	3	2	2
4	2	3	3	2	3	2

TABLE 5-continued

Effect of rhPDGF-BB on collagen organization using an analog scale (0 = none to 3 = highly organized) at 7- and 21-days following treatment.

		Groups				
Animal Number	Base-line	No Tx	Vehicle	3.24 μg/kg	32.4 μg/kg	324 μg/kg
5	3	2	3	2	3	3
6	1	3	3	3	2	3
Mean	1.5	2.833	2.667	2.667	2.667	2.667
SD	0.837	0.408	0.516	0.516	0.516	0.516

Biomechanics: Effect of rhPDGF-BB on Maximum Load to Rupture

In this model, the non treated group spontaneously repaired as a function of time based on the maximum load to rupture values (FIG. **11**). The mean maximum load to rupture values at day 7 post-treatment were significantly increased (~43% and 27%, respectively) in the 32.4 μg/kg dose-group vs. vehicle control and the no-treatment groups (FIG. **11**, Day 7 Post Tx). By day 21 post-treatment, the maximum load to rupture was still significantly increased compared to the vehicle control (FIG. **11**, Day 21 Post Tx). At day 21 post-treatment, the mean maximum load for the 32.4 μg/kg dose-group and no treatment groups was similar, indicating rhPDGF-BB treatment increased the rate of repair over no treatment. However, the vehicle and 324 μg/kg rhPDGF-BB groups had significantly lower maximum load to rupture values than the 32.4 μg/kg dose-group and no treatment group at day 21 post-dose. Data reported are means of Maximum load to rupture (±SEM) of n=9 animals per group; +$p<0.05$ vs "vehicle" group, **$p<0.05$ vs "no treatment" group.

Table 6 represents the mechanical strength of the unharmed contralateral tendons and rhPDGF-BB treated and non-treated tendons.

TABLE 6

Maximum Load to Rupture values (N ± SEM) for Achilles Tendons at 7-, 14- and 28-days Post-collagenase injection.

	Maximum Load to Rupture (N ± SEM)			
	Day 7 Baseline	Day 14 (Day 7 Post-Tx)	Day 28 (Day 21 Post-Tx)	Delta Δ (Compared to Vehicle)
Unharmed (Contralateral Legs without Collagenase Injection)	17.36 (2.18)	19.03 (0.67)	27.98 (1.43)	0.31 (Day 7 Post-Tx) 5.96 (Day 21 Post-Tx)
No Treatment (With Collagenase Injection without Vehicle or rhPDGF-BB)	15.68 (1.84)	21.06 (1.02)	30.86 (1.71)	2.34 (Day 7 Post-Tx) 12.14 (Day 21 Post-Tx)
Vehicle (With Collagenase Injection and treated with 20 mM Sodium acetate)	15.68 (1.84)	18.72 (1.92)	22.02 (1.75)	— —
3.24 μg/kg rhPDGF-BB (With Collagenase injection and treated with 3.24 μg/kg rhPDGF-BB)	15.68 (1.84)	22.65 (1.89)	23.67 (1.89)	
32.4 μg/kg rhPDGF-BB (With Collagenase injection and treated with 32.4 μg/kg rhPDGF-BB)	15.68 (1.84)	26.8 (1.98)	28.61 (1.45)	8.08 (Day 7 Post-Tx) 6.59 (Day 21 Post-Tx)
324 μg/kg rhPDGF-BB (With Collagenase injection and treated with 324 μg/kg rhPDGF-BB)	15.68 (1.84)	17.13 (1.89)	20.98 (1.89)	

Data reported are means of Maximum load to rupture (±SEM) of n = 9 animals per group.

The mean maximum load to rupture value in the 32.4 μg/kg rhPDGF-BB group (26.8 N) at Day 14-post collagenase injection was increased by 41% over the unharmed tendons (19.03 N) at Day 14-post collagenase injection. This suggests that biomechanical properties in the 32.4 μg/kg rhPDGF-BB group matured faster than the normal, developing tendon. Further, the mean maximum load to rupture of the 32.4 μg/kg rhPDGF-BB group (26.8 N) at Day 14-post collagenase injection approached that of the unharmed tendons (27.98 N) at Day 28-post collagenase injection. The maximum load to rupture values in the unharmed and no treatment (collagenase injected) groups at days 7, 14 and 28 were similar. At day 14 (Day 7 Post Tx), the 32.4 μg/kg rhPDGF-BB group had higher maximum load to rupture values than the vehicle, unharmed and no treatment groups, with increases of 43%, 41%, and 27%, respectively. However, at day 28 (Day 21 Post Tx) the maximum load to rupture in the unharmed, no treatment and 32.4 μg/kg rhPDGF-BB groups was similar (Table 6).

Conclusions

In-Life Parameters

The ankle thickness results demonstrated that 7-days following rhPDGF-BB treatment there is a dose-dependent increase in tendon size but by 21-days that growth has stunted and the tissue remodels to a decreased size.

There was no significant difference in the body weights across groups and time points.

Microscopic Assessment

rhPDGF-BB increased cellular proliferation, specifically fibroblastic in nature. Increases in cellular proliferation and microscopic tendon widths were reversible, indicating a possible adaptation phase to remodel the tissue.

No local adverse effects from rhPDGF-BB were observed following a single time intra-tendon delivery over a 3-week time period under the conditions of this study. There was no abnormal bone or tendon growth, and no bone resorption was identified. Inflammation was mononuclear in nature. The morphology of the cells was fibroblastic in nature.

Biomechanics

The biomechanical load to rupture data indicated that rhPDGF-BB initiated a faster repair response in mechanical strength of the tendon when compared to the non-rhPDGF-BB-treated cohorts. Although there was a return to baseline for cell proliferation and tendon width by day 21 post-treatment, this did not result in a biomechanical loss of tendon strength.

Summary

The biological and biomechanical outcomes in this study validated the local safety of rhPDGF-BB injected into the tendon. Following a onetime rhPDGF-BB injection, there was an initial stage of tendon growth that abated over the 21-day time period. This study measured tendon width under a microscope using an ocular micrometer and cell proliferation using PCNA immunostaining. The results from those measurements indicated that animals treated with 32.4 μg/kg rhPDGF-BB had an increase in microscopic tendon widths and cellular proliferation at 7-days post-treatment. However, by day 21 post-treatment, tendon widths and proliferation returned to control levels. Neither ectopic nor abnormal bone, nor aberrant tendon growth was observed over the 21 day time period following the rhPDGF-BB injection into the tendon.

The early increases in microscopic tendon width and cell proliferation corresponded to an increase in the mechanical strength of the tendon. Although there was a return to baseline for cell proliferation and tendon width by day 21 post-treatment, this did not result in a biomechanical loss of tendon strength, rather, the tendon biomechanical improvement was sustained.

The outcome from this study may be especially compelling in the clinic to treat lateral epicondylitis patients. In lateral epicondylitis there are degenerative changes to the extensor carpi-radialis brevis (ECRB) tendon that manifest as pain and functional decrement of the involved arm and hand to tolerate load. It is expected that increased biomechanical strength and structural modification of the tendon as a consequence of rhPDGF-BB therapy that were shown in the rat Achilles tendinopathy model described in this study, will translate clinically into pain abrogation and restoration of function for patients suffering from lateral epicondylitis.

Example 4: Pharmacokinetics of Recombinant Human Platelet-Derived Growth Factor-BB (rhPDGF-BB) in Sprague-Dawley Rats Following Intravenous Administration of rhPDGF-BB

The purpose of this study was to evaluate the pharmacokinetics of rhPDGF-BB administered as a single intravenous dose to male Sprague-Dawley rats. This study was designed to assess the clearance of naïve rhPDGF-BB from body fluid (serum) following intravenous administration. To better understand the pharmacokinetic and pharmcodynamic nature of rhPDGF-BB, systemic clearance following intravenous exposure was determined. We hypothesized that rhPDGF-BB will exhibit a fast rate of clearance following intravenous administration.

Study Design

Rat Model

Rat is a commonly used rodent model for evaluating the pharmacokinetic and toxicity of various classes of chemicals and a large historical database exists for the rat. A total of forty eight (48) male Sprague Dawley rats were used in this study. The animals were divided into 2 groups with 6 animals/group/timepoint (Table 7). This study was designed to use the fewest number of animals possible, consistent with the objective of the study, the scientific needs of the inventors and contemporary scientific standards. The design provided sufficient group sizes to allow for meaningful analysis of data. rhPDGF-BB was administered through intravenous delivery with insulin syringes (28.5 G) into the lateral tail-vein.

Test and Control Articles

Test Article was 0.4 mg/ml rhPDGF-BB in 20 mM sodium acetate buffer, pH: 6.0+/−0.5. Control Article was 20 mM sodium acetate buffer, pH 6.0+/−0.5.

At study initiation, at least two unopened, unused vials of the 0.4 mg/ml rhPDGF-BB and 20 mM sodium acetate (Acetate) buffer test articles were retained under the same storage conditions (4° C.) as the vials used for dosing, stability and concentration analysis. Stability and dose verification analyses were performed, which consisted of UV/Vis spectrophotometry and reverse phase HPLC analyses (Appendix II).

Standard laboratory safety procedures were employed for handling the test and control articles. Specifically, gloves, facemask, gown (or lab coat) and eye protection were worn while preparing and administering doses.

Test System

Forty-eight (48) male Sprague Dawley rats were used in this study. The rats used in this study were selected based on their weights. Average weight was approximately 227 grams at the time of treatment. Each rat was identified by a unique tail number that was written with permanent marker. Food

and water was withheld for appropriate study-related events such as anesthesia but was otherwise provided ad libitum. Prior to study selection, all animals were screened by visual examination.

Test Article Administration

Intravenous delivery was chosen to achieve 100% bioavailability and pharmacokinetic properties of rhPDGF-BB in serum. The dose level was selected based on the previous dose-response efficacy study of intra-tendon application of rhPDGF-BB in rat tendon collagenase model (see Example 3). The maximum dose concentration to be used in this study is 100 μg or 0.44 mg/kg, based on rats weighing 0.227 kg.

Forty-eight rats were weighed and randomly distributed into two groups of twenty-four rats/group. Rats were assigned randomly to each group according to their body weights.

Body weights were recorded at pre-dose. Group 1 animals received a single intravenous dose of rhPDGF-BB at 0.44 mg/kg (440 μg/kg) at a target dose volume of 1.1 mL/kg. Group 2 animals received vehicle control (NaOAc buffer) at a target dose volume of 1.1 mL/kg. Intravenous injection was achieved by lateral tail vein approach using insulin syringes (28.5 G). Approximately 300 μl serum was collected.

TABLE 7

Treatment Groups

Group number	Treatment Group	Route of Delivery	Animals (n)	rhPDGF-BB (mg/kg)	Target Volume (mL/kg)	Blood Collection Times*
1	rhPDGF-BB	Intravenous (IV)	24	0.44	1.1	1, 5, 10, 20, 60 minutes, 4, 8, 24, 48, 72, 96 and 168 hours
2	NaOAc	Intravenous (IV)	24	—	1.1	1, 5, 10, 20, 60 minutes, 4, 8, 24, 48, 72, 96 and 168 hours

*Blood collection times:
Animals 1-6 in all groups = Baseline, 1 min, 1 hr, 48 hr
Animals 7-12 in all groups = Baseline, 5 min, 4 hr, 72 hr
Animals 13-18 in all groups = Baseline, 10 min, 8 hr, 96 hr
Animals 19-24 in all groups = Baseline, 20 min, 24 hr, 168 hr

Clinical Observations

Animals were observed at least daily until sacrifice. Body weights were recorded prior to the rhPDGF-BB injection and before sacrifice. Food consumption was qualitative.

All animals were sacrificed at the appropriate study end points. Upon the completion of the in-life treatment groups, animals were euthanized through CO2 overdose. Death was confirmed by lack of reflexes (blinking, withdrawal, etc.). No gross or histopathology was conducted in this study. No unscheduled animal deaths were recorded.

Serum Collection

Approximately 600 μl blood was collected in serum tubes and centrifuged at 1,800 g at room temperature for 10 minutes to obtain serum. Approximately 300 μl serum was provided in 2 mL eppendorf tubes. The serum was stored at −70 degrees C. prior to analysis.

Serum Analysis

rhPDGF-BB serum concentrations were measured at each time point. rhPDGF-BB was quantified using the Quantikine ELISA kit from R&D systems.

Pharmacokinetic Analysis

A non-compartmental module of WinNonlin was used to calculate the following parameters: terminal half-life (t½), Tmax, Cmax, AUC0-last and CL. The analysis were performed using the amount of rhPDGF-BB present at different timepoints as determined in the serum using Quantikine ELISA kit assay.

Statistics

Statistical analyses were limited to descriptive parameters such as means, standard deviations, and coefficient of variation, as appropriate.

Results

Average body weight of all the animals at the time of treatment was 227 grams. Animals received an average dose of 440.53 μg/kg rhPDGF-BB.

The mean serum rhPDGF-BB concentration-time values are illustrated in FIG. **12**. The Cmax (6161.2 ng/mL) was achieved at 1 minute post dose. Thereafter there was a decrease in rhPDGF-BB concentration between 5 minutes and 1 hour. rhPDGF-BB concentrations were below level of quantitation (<0.156 ng/mL) from 1 to 168 hours.

Table 8 represents the pharmacokinetic disposition of IV administered rhPDGF-BB in male Sprague-Dawley rats. The average dose delivered was 440 μg/kg. Tmax was observed at 0.0167 hours (1 minute) with a Cmax of 6161.2 ng/mL. The AUC0-last was 375.64 hr*ng/mL and the clearance (CL) was 17.5 mL/min/kg.

TABLE 8

Pharmacokinetic Data Analysis for IV dosing

Route	Dose (μg/kg)	Cmax (ng/mL)	Tmax (hours)	AUC0-last (hr * ng/mL)	CL (mL/min/kg)
IV	440	6161.2	0.0167	375.64	17.5

Conclusion

The intravenous (IV) administration of rhPDGF-BB resulted in a high initial systemic exposure. It is an intermediate clearance molecule that is rapidly eliminated from the blood over the first 10 minutes after dosing.

Example 5: Pharmacokinetics of rhPDGF-BB in Sprague Dawley Rats Following Intra-Tendon Administration of rhPDGF-BB

The purpose of this study was to evaluate the pharmacokinetics of rhPDGF-BB administered as a single intra-tendon dose to male Sprague-Dawley rats. This study was designed to assess the rhPDGF-BB systemic exposure and clearance following intra-tendon delivery.

Study Design

Rat Model

Rat is a commonly used rodent model for evaluating the pharmacokinetic and toxicity of various classes of chemicals and a large historical database exists for the rat. A total of thirty two (32) male Sprague Dawley rats were used in this study. Animals were randomly distributed into four groups of 8 animals/group (Table 9). This study was designed to use the fewest number of animals possible, consistent with the objective of the study, the scientific needs of the inventors and contemporary scientific standards. The design provides sufficient group sizes to allow for meaningful analysis of data.

Test and Control Articles

Test articles were as follows: (1) 3.4 mg/ml rhPDGF-BB in 20 mM sodium acetate buffer, pH: 6.0+/−0.5; and (2) 0.34 mg/ml rhPDGF-BB in 20 mM sodium acetate buffer, pH: 6.0+/−0.5. The control article was 20 mM sodium acetate buffer, pH 6.0+/−0.5.

At study initiation, at least two unopened, unused vials of the 3.4 and 0.34 mg/ml rhPDGF-BB and 20 mM sodium acetate (Acetate) buffer test and control articles were retained under the same storage conditions (4° C.) as the vials used for dosing, stability and concentration analysis. Stability and dose verification analyses were performed, which consisted of UV/Vis spectrophotometry and reverse phase HPLC analyses.

Doses included in this study were 1.02, 10.2 and 102 μg rhPDGF-BB. The 102 and 10.2 μg doses were achieved by 30 μl injection of 3.4 mg/ml and 0.34 mg/ml, respectively. For the 1.02 μg dose, 0.34 mg/ml was diluted 1:10 with NaOAc buffer.

Standard laboratory safety procedures were employed for handling the test and control articles. Specifically, gloves, facemask, gown (or lab coat) and eye protection were worn while preparing and administering doses.

Test System

Thirty-two (32) male Sprague Dawley rats were used in this study, and were selected based on their weights (approximately 294 grams at the time of injection). Rats were assigned randomly to each group according to their body weights.

Each rat was identified by a unique number that was written on their tails. Food and water was withheld for appropriate study-related events such as anesthesia but was otherwise provided ad libitum. Prior to study selection, all animals were screened by visual examination.

Treatment of the animals was in accordance with FIMR's CCP standard procedures that adhered to the regulations outlined in the USDA Animal Welfare Act (9 CFR, Parts 1, 2, and 3) and the conditions specified in The Guide for Care and Use of Laboratory Animals (ILAR publication, 1996, National Academy Press).

Test Article Administration

The intra-Achilles tendon administration mimics the administration of rhPDGF-BB in the clinic. The injection site at tendon-calcaneous junction mimics the insertional site of tendon and bone.

The dose levels were selected based on the previous dose-response efficacy study of intra-tendon application of rhPDGF-BB in rat tendon collagenase model (see Example 3). The maximum dose concentration used in this study was 102 μg or 0.347 mg/kg, based on rats weighing 0.294 kg.

Thirty-two male Sprague-Dawley rats with an average weight of 294 grams were randomly distributed into four groups of 8 animals/group. Group 1, 2 and 3 received a single intra-tendon average bolus dose of 347 μg/kg, 34.7 μg/kg and 3.47 μg/kg rhPDGF-BB, respectively, in a target delivery volume of 30 μL per animal (0.102 mL/kg) in the right Achilles tendon near the osteotendinous junction. Group 4 received a single intra-tendon injection of 20 mM sodium acetate buffer in a target delivery volume of 30 μL per animal. Treatment was injected into the right Achilles tendon near the osteotendinous junction using insulin syringes (28.5 G). Animals were bled via tail vein with blank 1 cc syringes (26 G) (~400 μl whole blood, ~200 μl of serum) for serum at the bleed times listed below. rhPDGF-BB in the serum was measured using Quantikine ELISA.

TABLE 9

Treatment Groups					
Group number	Treatment Group	Animals (n)	rhPDGF-BB (μg/kg)	Target Volume (mL/kg)	Blood Collection Times*
1	rhPDGF-BB	8	347	0.102	1, 5, 10, 20 minutes, 4, 8, 24, 48, 72, 96 and 168 hours
2	rhPDGF-BB	8	34.7	0.102	1, 5, 10, 20 minutes, 4, 8, 24, 48, 72, 96 and 168 hours
3	rhPDGF-BB	8	3.47	0.102	1, 5, 10, 20 minutes, 4, 8, 24, 48, 72, 96 and 168 hours
4	NaOAc (20 mM sodium acetate)	8	—	0.102	1, 5, 10, 20 minutes, 4, 8, 24, 48, 72, 96 and 168 hours

*Blood collection times were:
Animals 1-4 in all groups = Baseline, 1 min, 10 min, 20 min, 4 hr, 24 hr and 72 hr
Animals 5-8 in all groups = Baseline, 5 min, 8 hr, 48 hr, 96 hr and 168 hours

Approximately 400 μl blood was collected in serum tubes and centrifuged at 1,800 g at room temperature for 10 minutes to obtain serum. Approximately 200 μl serum was provided in 2 mL eppendorf tubes. The serum was stored at −70 degrees C. prior to analyses to measure the amount of rhPDGF-BB on the stored serum samples.

Clinical Observations

Animals were observed at least daily until sacrifice. Body weights were recorded prior to the rhPDGF-BB injection. Food consumption was qualitative. No unscheduled animal deaths were recorded.

All animals were sacrificed at the appropriate study end points. Upon the completion of the in-life treatment groups, animals were euthanized through CO_2 overdose. Death was confirmed by lack of reflexes (blinking, withdrawal, etc.). No gross or histopathology was conducted in this study.

Serum Analysis

rhPDGF-BB serum concentrations were measured at each time point. rhPDGF-BB was quantified using the Quantikine® Human PDGF-BB Immunoassay for the Quantitative Determination of Human Platelet Derived Growth Factor-BB Concentrations ELISA kit from R&D Systems (Minneapolis, Minn.) as follows.

First, all reagents in the kit were brought to room temperature before use. Next, a standard curve of rhPDGF-BB was prepared using the same lot of rhPDGF-BB used in the test samples. The rhPDGF-BB was diluted to 10 ng/ml using the diluent buffer provided with the kit. That solution was then serially diluted 1:2 down to a concentration of 0.15625 ng/ml. The samples to be tested were diluted using the same diluent buffer, such that the concentration values fall well within the rhPDGF-BB standard curve of 0.15625 ng/ml to 10 ng/ml.

The number of wells needed to assay all samples in duplicate was determined, and each 8-well strip on the microtiter plates was numbered appropriately. 100 μl per well of Assay Diluent RD1X was added to each well, followed by 100 μl of standards and samples. The plate was then covered with an adhesive cover and incubated at room temperature for approximately 2 hours on an orbital shaker (set to between 50-70 rotations/minute). Each well was aspirated and washed with 300 μL Wash Buffer. Repeat 4 times. Next, 200 μl anti-rhPDGF-BB Conjugate (supplied with R & D kit, no dilution necessary) was added to each well. The plate was covered with a new adhesive cover and incubated at room temperature for approximately 1.5 hours on an orbital shaker set to between 50-70 rotations/minute. The aspiration and wash steps were repeated, and then 200 μl Substrate solution (supplied with R & D kit, no dilution necessary) was added to each well. The samples were then incubated at room temperature in the dark for approximately 30 minutes on an orbital shaker. 50 μl Stop solution (supplied with R & D kit, no dilution necessary) was added to each well and the solution was mixed by pipetting it up-and-down 2-4 times with an 8-channel multi-channel pipette if color development was uneven. The optical density of each well was determined in a microplate reader set to 450 nm (with wavelength correction of 540 nm) within 30 minutes of the addition of Stop Solution. The optical density readings were exported to Microsoft Excel for analysis.

Mean values were calculated for each of the samples. rhPDGF-BB concentrations were calculated for each test sample using the standard curve on each plate. The total amount of protein present in each sample was calculated using rhPDGF-BB concentration and the total volume of each sample.

Pharmacokinetic Analysis

A non-compartmental module of WinNonlin was used to calculate the following parameters: terminal half-life ($t_{1/2}$), time of maximum observed concentration (T_{max}), maximum observed concentration (C_{max}) occurring at T_{max}, area under the drug concentration v. time curve from t=0 hours to t=time of last observation ($AUC_{0\text{-}last}$) and bioavailability (% F). The analyses were performed using the amount of rhPDGF-BB present at different time points as determined in the serum using Quantikine ELISA kit assay.

Other parameters can be calculated, such as: area under the drug concentration v. time curve from time=0 extrapolated to infinity, based on last observed concentration (AUC_{inf}), total body clearance for intravenous administration (CL), and total body clearance for intra-tendon administration (CL/F).

Statistics

Statistical analyses were limited to descriptive parameters such as means, standard deviations, and coefficient of variation, as appropriate.

Results

The average body weight of all the animals at the time of treatment was 294 grams. Animals received an average dose of 347 μg/kg (102 μg), 34.7 μg/kg (10.2 μg) or 3.47 μg/kg (1.02 μg) rhPDGF-BB.

The mean serum rhPDGF-BB concentration-time values for 347 μg/kg dose group are illustrated in FIG. **13**. A decrease in concentration of rhPDGF-BB in serum between 5 minutes and 8 hours was observed. From 8 to 168 hours the concentration of rhPDGF-BB in serum was below the level of quantification (<0.156 ng/mL) for the ELISA. The rhPDGF-BB concentration in the serum for 34.7 μg/kg and 3.47 μg/kg dose groups were below the level of quantification (<0.156 ng/mL) at all time points.

Table 10 represents the pharmacokinetic analysis of the parameters for intratendon (IT) dosing of rhPDGF-BB in male Sprague-Dawley rats for the 347 μg/kg dose group, and for intravenous (IV) dosing for the 440 μg/kg dose group described in Example 4. The Tmax was observed at 0.083 hours (4.98 minutes) with a Cmax concentration of 16.3 ng/mL. The AUC0-last was 12.58 ng*hr/mL and the bioavailability was 3.34%. The rhPDGF-BB concentration in the serum for 34.7 μg/kg and 3.47 μg/kg dose groups were below the level of quantification (<0.156 ng/mL) at all time points and thus the pharmacokinetic parameters were not calculated.

TABLE 10

Pharmacokinetic Data Analysis for IT dosing (347 μg/kg dose group) and IV dosing (440 μg/kg dose group)

Route	Dose (μg/kg)	C_{max} (ng/mL)	T_{max} (hours)	$AUC_{0\text{-}last}$ (ng * hr/mL)	% F
IT	347	16.3	0.0833	12.58	3.34
IV	440	6161.2	0.0167	375.64	—

Conclusion

The intra-tendon (IT) administration of rhPDGF-BB resulted in a rapid initial low systemic exposure. No detectable serum concentrations of rhPDGF-BB were observed at doses below 347 μg/kg rhPDGF-BB.

At the 347 μg/kg rhPDGF-BB IT dose, approximately 3.34% of the administered dose reached systemic circulation, while Cmax values are only 0.26% of values seen after IV dosing. Therefore, rhPDGF-BB following intra-tendon administration is rapidly cleared following absorption into the serum. Given the low bioavailability (~3.34%) of rhPDGF-BB following intra-tendon administration, this surprisingly predicts that rhPDGF-BB is retained at the site of action.

Example 6: A Phase II Randomized, Single Ascending Dose, Double-Blinded, Placebo Controlled, Multi-Center Study of the Effects of rhPDGF-BB Injection on Lateral Epicondylitis

The purpose of this study is to evaluate the effectiveness of rhPDGF-BB Injection as a treatment for lateral epicondylitis, also known as "tennis elbow."

Study Sites/Study Groups.

The study is performed at up to six clinical sites. The study population is one hundred (100) subjects randomized into four groups with twenty five (25) subjects per group. Each cohort includes 5 placebo patients and 20 active treatment patients.

Study Population:

Subjects presenting with a clinical diagnosis of lateral epicondylitis having failed conservative treatment for three (3) months.

Study Design.

The study is a Phase II randomized, single ascending dose, double-blinded, placebo controlled, multi-center study. Eligible subjects meeting inclusion criteria for study enrollment are enrolled after obtaining informed consent for study participation. Subjects are followed for 24 weeks post-procedure. Randomization following study enrollment assigns the subject to one of the following treatment groups following a 1:1:1:1:1 schema: (1) Dose A: Buffer alone—Control Group; (2) Dose B: Buffer+0.45 mg rhPDGF-BB; (3) Dose C: Buffer+0.75 mg rhPDGF-BB; (4) Dose D: Buffer+1.5 mg rhPDGF-BB; and (5) Dose E: Buffer+3.0 mg rhPDGF-BB. The total volume for all doses is 1.5 ml of rhPDGF-BB solution per dose (corresponding to treatment groups of 0.3 mg/ml, 0.5 mg/ml, 1.0 mg/ml, and 2.0 mg/ml of rhPDGF-BB, respectively, and corresponding to 6.4, 10.7, 21.4, and 42.9 μg rhPDGF-BB/kg based on a 70 kg human, respectively). Buffer is 20 mM sodium acetate, pH=6.0.

Randomization is done using a tiered escalation approach. Initial randomization follows a statistically powered escalation scheme assigning subjects to treatment groups utilizing the following pattern: the predetermined, statistically powered number of subjects are randomized to either Dose A (Buffer alone—Control Group) or Dose B (Buffer+0.3 mg/ml rhPDGF-BB). Once the predetermined number is reached for this initial dose tolerance (Dose B), the 2^{nd} tier randomization adds the predetermined statistically powered number of subjects to be randomized to either Dose A, Dose B or the additional option of Dose C (Buffer+0.5 mg/ml rhPDGF-BB). This same pattern, adding the statistically powered number of subjects within each tier of the randomization scheme, is repeated until Dose D (Buffer+1.0 mg/ml rhPDGF-BB) and Dose E ((Buffer+2.0 mg/ml rhPDGF-BB) are introduced into the randomization scheme and study enrollment targets are reached.

A single injection of the assigned dose is administered to the tendon using the "peppering technique". The "peppering technique" is an injection method whereby after the needle is inserted into the tender area, multiple small injections are performed by withdrawing, redirecting and reinserting the needle without emerging from the skin.

Subjects are evaluated for local reaction to the injection site (redness, swelling, itching, pain), any increase in pain to the area of chronic injury and any sign of allergic reaction. If subjects report an incidence of the above symptoms, the severity and relationship to the study drug is determined following assessment of the subject and determination by the investigator and documented in the assigned study eCRF. If the severity of the symptom and association is determined to be related to the rhPDGF-BB treatment, the information is immediately to the sponsor as well as appropriate regulatory bodies. A determination is then made whether to continue enrollment or stop subject enrollment at that time.

A pre-procedure Anterior-Posterior (AP) and Lateral x-ray is obtained for baseline imaging and is done up to four (4) weeks prior to the procedure. Additional AP and Lateral x-rays are obtained per study protocol at twenty four (24) weeks post-procedure. Final evaluation of safety is done when all subjects have completed the twenty four (24) week follow-up visit.

Inclusion Criteria.

Subjects included in this study are those whose symptoms can be reproduced with resisted supination or wrist dorsiflexion, and have a clinical diagnosis of lateral epicondylitis and are ≥21 years of age.

Exclusion Criteria.

Subjects excluded from this study are those having had previous corticosteroid injection therapy within the past three (3) months or having undergone surgical intervention for the treatment of lateral epicondylitis; subjects with an allergy to yeast-derived products; subjects with a history of carpal tunnel syndrome; subjects with a history of cervical radiculopathy; and subjects who have had trauma to the affected elbow within six (6) months of treatment.

Duration of Study.

Enrollment is approximately 9 months. Follow-up visits include grip-strength testing and a physical exam of the extremity for up to twenty four (24) weeks post-procedure. Safety endpoints are monitored until last visit at twenty-four (24) weeks.

Primary Outcome Measures.

(1) Safety. Safety and tolerability of rhPDGF-BB are assessed by evaluating the occurrence of adverse events. rhPDGF-BB is safe and tolerated by the subjects.

Secondary Outcome Measures.

The following assessments are completed at visit two prior to the study procedure and at post-procedure study visits at four (4), eight (8), twelve (12) and twenty-four (24) weeks: (1) Disabilities of the Arm, Shoulder and Hand Score (DASH). (2) Visual Analog Score (VAS). (3) Sincerity of effort measured by grip strength testing. Treatment with rhPDGF-BB results in one or more beneficial changes in the clinical outcome for the tendon, such as an improved change from pretreatment score (DASH and VAS), a decrease in pain with applied pressure and/or wrist flexion, increased mobility of the effected extremity, and/or increased grip strength.

Example 7: Effect of rhPDGF-BB-Coated Sutures on Tendon Healing in a Rat Model: A Histological and Biomechanical Study

Abstract

Introduction.

Achilles tendon tears are common injuries that often require surgical repair. The aim of this study was twofold: (1) determine whether sutures coated with rhPDGF-BB could successfully deliver appropriate amounts of the factor to the repair site, and (2) determine if the sutures coated with rhPDGF-BB would improve healing in a rat achilles tendon model based on biomechanics and histology.

Methods.

4-0 Vicryl suture was coated with varying concentrations of rhPDGF (0, 0.3, 1.0, and 10.0 mg/ml) using a dip-coating process previously described. The 0 rhPDGF group served as the control. ELISA was used to determine resultant concentrations of rhPDGF on the suture after being coated in the varying dipcoat solutions.

Rat Achilles tendons were transected and repaired acutely using one of the four suture types. Tendons were harvested at 4 weeks postoperatively. Histology sections from each specimen were scored for collagen organization and angiogenesis. Uniaxial tensile biomechanical analysis was per-

formed on each specimen providing load and extension data. The raw data was analyzed for the Young's Modulus, Ultimate Tensile Strength and Elastic toughness of each specimen.

Results.

The sutures were successfully coated with the rhPDGF with higher dip-coat concentrations resulting in larger amounts of rhPDGF on the sutures. The histological analysis demonstrated no significant differences in collagen score or angiogenesis between control and PDGF groups. The biomechanical results demonstrated a significant difference in ultimate tensile stress between control (1.0±0.2 MPa) and high dose PDGF groups (1.9±0.5 MPa and 2.1±0.5 MPa). Tensile Young's Modulus was significantly higher in PDGF 10 mg/ml group (7.22, SD 3.79) than all the other groups. This demonstrated a positive dose response and improved strength with PDGF coated sutures.

Conclusion.

This study proved our hypothesis that rhPDGF-coated sutures could improve material properties of repaired tendons in a positive, dose-dependent fashion.

Introduction

In the current study, we hypothesized that 4-0 Vicryl sutures could be successfully coated with reproducible amounts of rhPDGF-BB, and that augmentation of rat Achilles tendon repair with rhPDGF-BB-coated sutures would enhance the repair in a dose-dependent manner, as assessed biomechanically and histologically.

Materials and Methods

The study was carried out in two parts: 1) in vitro suture coating and analysis and 2) in vivo Achilles tendon repair in a rat model. The procedure was approved by the IUCAC.

Part 1: Suture Coating:

Four groups of 4-0 Vicryl sutures (Ethicon, Somerville, N.J.) were coated with: (1) 20 mM sodium acetate buffer (carrier control), (2) 0.3 mg/ml rhPDGF-BB in buffer, (3) 1.0 mg/ml rhPDGF-BB in buffer, and (4) 10.0 mg/ml rhPDGF-BB in buffer using a dip-coating process, as described previously (Dines J, Weber L, Razzano P, et al. The Effect of Growth Differentiation Factor-5-Coated Sutures on Tendon Repair in a Rat Model. J Shoulder Elbow Surg 2007; 16:215 S-221S). Briefly, after treatment with 70% ethanol the sutures (with needles) were submerged in sodium acetate buffer, with or without rhPDGF-BB (0, 0.3, 1.0, and 10.0 mg/ml), for 30 minutes and then air-dried. Unlike the process described by Dines et al., no gelatin was used in the coating solution. Sutures were trimmed to 15 cm lengths for use in the in vivo study. The remaining lengths of the trimmed sutures were used for in vitro analysis.

In Vitro rhPDGF-BB Release:

Sutures (n=5/group) coated in solutions of acetate buffer (group 1) or rhPDGF-BB (group 2-4) were placed in elution buffer (Minimum essential medium with 2% fetal bovine serum, 1% penicillin-streptomycin, 1% L-Glutamine, and 1% HEPES buffer) and incubated at 37° C. on a rocking platform. The elution buffer was fully exchanged at time points of 1, 6, 24, and 48 hours. The total rhPDGF-BB released at each time point was determined using a PDGF-BB ELISA (human PDGF-BB DuoSet, R&D Systems, Minneapolis, Minn.).

Part II: Study Design:

48 Sprague-Dawley rats (350-400 grams) were randomized in a blinded fashion to one of the four treatment groups (n=12 per group). The groups were composed of the four different concentrations of rhPDGF-BB in the dip-coating solution described above with a control group (0 mg/ml rhPDGF-BB) and three experimental groups (0.3, 1.0, and 10.0 mg/ml rhPDGF-BB initial coating concentration).

Surgical Procedure:

All surgeries were performed under sterile conditions. A 1.5 cm skin incision was made over the Achilles tendon. Blunt dissection was used to expose the Achilles tendon. At this point the tendon was transected with a scalpel blade proximal to its insertion on the calcaneus. The tendon was immediately repaired using one modified Mason-Allen stitch and one simple interrupted stitch using sutures from one of the four groups. There was no difficulty in executing either stitch due to the small size of the rat Achilles tendon. The skin was closed with interrupted uncoated Vicryl sutures. Animals were allowed to ambulate normally following the surgical repair. After four weeks the rats were sacrificed and tendons, including a bone block from the calcaneus and the proximal gastroc-soleus muscle complex, were harvested. The specimens were randomly assigned to biomechanical analysis (n=8/group, fresh-frozen) or histological analysis (n=4/group, formalin-fixed).

Biomechanics:

Uniaxial tensile biomechanical analysis was performed on each specimen using an Instron system (Model No. 5566) fitted with a 100N load cell with load accuracy of +/−0.5%. After thawing at 4° C. for up to 4 hours in phosphate-buffered saline (PBS) containing protease inhibitors, samples were dissected to remove excess muscle and the calcaneus and gastroc-soleus ends were wrapped in 220 grit sandpaper. The specimen was secured between pneumatic grips and submerged in a bath of PBS. Samples were pre-loaded (1N) in tension and sample dimensions were measured. The tendon was then subjected to tensile extension at a strain rate of 0.25%/sec. Specimens were pulled to failure and the resulting load and extension data were collected with a personal computer, with data acquired at 10 Hz. After testing, the collected data was analyzed to determine (1) linear stiffness and (2) elastic modulus from the linear portion of the load-displacement or stress-strain curve, respectively. The maximum load and ultimate tensile strength were also calculated from the loading curves.

Histology:

Tendon specimens were detached from the calcaneus at the Achilles tendon insertion site and the repaired Achilles tendons were processed and embedded in paraffin. Saggital sections from each specimen were stained with Mallory's trichrome or Sirius red. Slides were imaged and scored by three blinded observers using a scoring system for collagen organization and degree of angiogenesis, as previously described (Dines J, Weber L, Razzano P, et al. The Effect of Growth Differentiation Factor-5-Coated Sutures on Tendon Repair in a Rat Model. J Shoulder Elbow Surg 2007; 16:2155-2215). Three independent observers who were blinded to treatment group assessed each slide. Total scores were computed for each treatment group and compared for statistical significance.

Statistical Analysis:

The amount of rhPDGF-BB released in vitro was analyzed using a repeated measures ANOVA, with time as the repeated measure. The cumulative amount of rhPDGF-BB released and the total dose delivered versus the initial coating concentration were fit with a nonlinear (log-log scale) least squares fit. A one-way ANOVA with a Bonferroni multiple comparison test was used to determine differences among groups for the biomechanical parameters. Statistical analysis on the histology grading scores was performed using a Kruskal-Wallis test with Dunn's multiple comparison post-hoc test. Biomechanics data are presented

as mean±SEM and histology scores are presented as median (range). Significance was determined at $p<0.05$.

Results

In Vitro rhPDGF-BB Release:

The in vitro release data are presented as the amount of rhPDGF-BB released, normalized by the length of the suture (ng/cm) (FIGS. **14**A and **14**B). In vitro release was measured in all groups including Group 1 (0 mg/ml) which was considered as the baseline measurement for the other groups (cumulative release: 1.3±0.1 ng/cm). A bolus release of rhPDGF-BB from the sutures was observed after the first hour of incubation (Group 2: 6.29±3.0 ng/cm; Group 3: 68.81±9.3 ng/cm; and Group 4: 5809.42±541.6 ng/cm) (FIG. **14**A). The initial bolus release was followed by a continuous, gradual release of additional rhPDGF-BB through the 48-hour time point. The cumulative amount of rhPDGF-BB released over the 48-hour incubation was dose-dependent with increased rhPDGF-BB released with higher concentrations of the dip-coating solution; Group 4 (10 mg/ml; 6495.9±552.6 ng/cm) was significantly increased ($p<0.001$) relative to Group 2 (0.3 mg/ml; 14.0±5.7 ng/cm) and Group 3 (1.0 mg/ml; 126.8±18.8 ng/cm) (FIG. **14**B). The cumulative amount of rhPDGF-BB released was not significantly different ($p>0.05$) among Group 2 and Group 3. The cumulative amount of rhPDGF-BB released (Y, ng/cm) was logarithmically proportional ($R^2=0.9575$) to the initial coating concentration (X, mg/ml) by the equation:

$$Y=10^{(1.711*\log(X)+2.102)}.$$

Surgical and Gross Observations:

All animals responded well to the surgery, with the exception of one animal in group 3 (assigned to histology) which died overnight following surgery secondary to complications from anesthesia. The length of suture used for the repair was consistent among groups (Group 1: 4.8±0.1 cm; Group 2: 4.7±0.2 cm; Group 3: 4.8±0.1 cm; and Group 4: 4.8±0.1 cm; $p=0.94$) (FIG. **14**D). Based on the mean amount of rhPDGF-BB released in vitro and the lengths of suture, the in vivo doses (mean±SD) for each group were calculated to be: Group 1: 0 ng; Group 2: 66.0±61.2 ng; Group 3: 602.5±190.9 ng; and Group 4: 31,342.6±6774.5 ng. Similar to the cumulative amount of rhPDGF-BB released, the in vivo dose delivered (Y, ng) was logarithmically proportional ($R^2=0.9859$) to the initial coating concentration (X, mg/ml) (FIG. **14**C) with the equation:

$$Y=10^{(1.732*\log(X)+2.757)}.$$

Biomechanics:

Five specimens were unable to be used for biomechanical analysis due to an error with the Instron testing machine on that day of testing. The resulting specimen numbers for biomechanical analysis were: n=7 (group 1, 2, and 3) and n=6 (group 4).

No significant differences ($p>0.16$) in the structural properties of the repaired tendons (ultimate load and stiffness) were observed, however, the mean values for the ultimate load (Group 1: 22.1±1.8 N; Group 2: 31.6±3.5 N; Group 3: 28.0±3.7 N; Group 4: 27.6±1.8 N) and stiffness (Group 1: 6.7±0.4 N/mm; Group 2: 8.9±0.8 N/mm; Group 3: 8.0±1.0 N/mm; Group 4: 7.9±0.7 N/mm) were consistently higher in the groups receiving rhPDGF-BB, relative to the control group (Group 1).

A significant decrease ($p<0.05$) in the cross-sectional area (CSA) was observed in Group 4 (0.14±0.05 cm^2) compared to Group 1 (0.21±0.03 cm^2) and Group 2 (0.23±0.04 cm^2). The CSA was also significantly decreased ($p<0.05$) in Group 3 (0.17±0.02 cm^2) relative to Group 2. The decrease in CSA resulted in significant differences in the material properties of the repaired tendons (ultimate tensile strength and elastic modulus). There was a significant increase ($p<0.05$) in the ultimate tensile strength in the 10.0 mg/ml rhPDGF-BB group (2.1±0.2 MPa), relative to the 0 mg/ml (1.0±0.1 MPa) and 0.3 mg/ml (1.4±0.1 MPa) rhPDGF-BB groups and in the 1.0 mg/ml (1.9±0.2 MPa) rhPDGF-BB group compared to the 0 mg/ml group. The elastic modulus was observed to be significantly increased ($p<0.05$) in the 10.0 mg/ml (7.22±1.5 MPa) rhPDGF-BB group compared to all of the other groups (0 mg/ml: 3.5±0.4 MPa; 0.3 mg/ml: 4.4±0.4 MPa; 1.0 mg/ml rhPDGF-BB: 4.9±0.7 MPa). The 0, 0.3, and 1.0 mg/ml rhPDGF-BB groups were not statistically different from each other.

Histology:

Histology was performed on four animals from each group (n=3 for group 3). Each section was scored by three graders and a mean score was determined. The mean scores are presented as median (range). Histological analysis demonstrated no significant differences in collagen organization or angiogenesis scores among groups. However, a trend towards a more normal appearance was observed in the rhPDGF-BB groups compared to the control group, particularly in the collagen organization scores.

DISCUSSION

In this study we demonstrated that rhPDGF-BB could be successfully coated onto Vicryl sutures, with the amount of rhPDGF-BB released from the sutures in vitro dependent on the initial coating concentration. No significant differences were observed in the structural mechanical properties (ultimate load and stiffness) or by histology, although there was a trend for improvement in these properties in the rhPDGF-BB-treated groups. A dose-dependent response to rhPDGF-BB-coated sutures was observed for the material biomechanical properties, as exhibited by increased material mechanical properties (ultimate tensile stress and elastic modulus).

Biomechanically, significant differences were observed with the highest dose of rhPDGF-BB for the ultimate strength and elastic modulus. The ultimate strength (also referred to as ultimate tensile strength or ultimate tensile stress) and elastic modulus (also referred to as Young's modulus) represent the structural properties (ultimate load and stiffness), normalized by the dimensional properties of the tendon (displacement and CSA), and are a measure of the quality of the tissue. In this study, the decrease in the CSA with increasing dose of rhPDGF-BB accounted for the increase in the material properties. A decrease in CSA is suggestive of a more organized tendon. Although a trend toward improved collagen organization with rhPDGF-BB was observed histologically, this score did not reach statistical significance as was observed for the CSA, potentially due to the small sample size allocated for histology. Regardless, the trend for improved collagen organization, combined with the decrease in the CSA, suggest that the highest dose of rhPDGF-BB promoted a better quality tendon tissue (increased ultimate strength and elastic modulus) relative to the control sutures.

Quantification of the applied dose of rhPDGF-BB is necessary to evaluate the efficiency of the suture coating process and the dose-dependent effect on tendon healing. In vitro analysis demonstrated a significant increase in the amount of rhPDGF-BB released from the highest coating concentration (10 mg/ml), however there was no significant difference noted at the two lower coating concentrations (0.3

and 1.0 mg/ml) even with a 9-fold difference in the average cumulative amount of rhPDGF-BB released (14.0±5.7 ng/cm vs. 126.8±18.8 ng/cm, respectively). This was consistent with the observation that the ultimate strength and elastic modulus were not significantly different among the two lower dose groups.

This study showed that delivery of rhPDGF-BB was able to augment the biological repair of the rat Achilles tendon. A limitation is this study is how the interpretation of these results is affected by the sample size used in this study. This study was designed with 8 animals/group for biomechanics and 4 animals/group for histology. Due to an error with the Instron testing device on one day of mechanical testing, 5 specimens were not included in the analysis, reducing the statistical power. As a result, smaller differences in properties such as the ultimate load and stiffness could not be deemed significant for the experimental groups, even when they appeared to be increased, on average, relative to the control group.

In the application of growth factors, where the results are often dose-dependent, delivery of larger doses may be required when the size of the animal increases. Preliminary investigations (data not shown) have exhibited a dependence of the delivered dose on both the initial coating concentration and the surface area of the suture, suggesting that scaling the dose for a larger animal is achievable.

The results demonstrated suggests that the use of rhPDGF-BB-coated sutures in clinical applications may have potential for improved tendon healing and increased function for the patient.

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We claim:

1. A method of treating a tendinopathy comprising administering to an affected tendon an effective amount of a composition comprising a PDGF and a buffer, wherein the effective amount of the composition comprises between about 75 μg and about 7,500 μg of PDGF per dose, and further wherein the administration to an affected site comprises direct injection into the affected tendon.

2. The method of claim **1**, wherein the tendinopathy is a tendinosis.

3. The method of claim **1**, wherein the tendinopathy is a tendinitis.

4. The method of claim **1**, wherein the tendinopathy is a tenosynovitis.

5. The method of claim **1**, wherein the PDGF is selected from the group consisting of PDGF-AA, PDGF-BB, PDGF-AB, PDGF-CC, and PDGF-DD.

6. The method of claim **5**, wherein the PDGF comprises PDGF-BB.

7. The method of claim **6**, wherein the effective amount of the composition comprises between about 400 μg to about 1000 μg of PDGF-BB per dose.

8. The method of claim **6**, wherein the effective amount of the composition comprises between about 500 μg to about 900 μg of PDGF-BB per dose.

9. The method of claim **6**, wherein the effective amount of the composition comprises between about 600 μg to about 800 μg of PDGF-BB per dose.

10. The method of claim **5**, wherein the PDGF comprises recombinant human (rh) PDGF-BB.

11. The method of claim **1**, wherein the composition has a volume of about 1.0 to about 2.0 ml per dose.

12. The method of claim **1**, wherein the buffer is selected from the group consisting of phosphate-buffered saline (PBS), sodium acetate, ammonium acetate, acetic acid, citric acid, sodium citrate, tris(hydroxymethyl)aminoethane (tris), N-2-hydroxyethylpiperazine-N'-2-ethanesulfonic acid (HEPES), 3-(N-morpholino) propane sulfonic acid (MOPS), 2-(N-morpholino)ethanesulfonic acid (MES), N-(2-acetamido)iminodiacetic acid (ADA), piperazine-N,N'-bis(2-ethanesulfonic acid) (PIPES), and N-(2-acetamido)-2-aminoethanesulfonic acid (ACES).

13. The method of claim **12**, wherein the buffer is sodium acetate at a concentration between about 10 mM and about 100 mM.

14. The method of claim **1**, wherein the composition has a pH between about 4.0 and about 7.0.

15. The method of claim **1**, wherein the tendinopathy is selected from the group consisting of Achilles tendinopathy, patellar tendinopathy, lateral epicondylitis, medial epicondylitis, plantar fasciitis, and rotator cuff tendinopathy.

16. The method of claim **1**, wherein the tendinopathy is lateral epicondylitis.

17. The method of claim **1**, wherein the composition is administered in more than one dose.

18. The method of claim **1**, wherein the composition is administered using a peppering technique, wherein the needle is inserted into the affected tendon and multiple small injections are performed by withdrawing, redirecting and reinserting the needle into the tendon without the needle to emerging from the skin.

19. The method of claim **1**, wherein the composition is administered once a week for up to six months.

20. The method of claim **1**, wherein the composition is administered twice a month for up to six months.

21. The method of claim **1**, wherein the composition is administered once a month for up to six months.

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